WG2 Summary: Part 2

Daniel M. Kaplan

ILLINOIS INSTITUTE OF TECHNOLOGY

Transforming Lives. Inventing the Future. www.iit.edu

Muon Collider 2011

Telluride, CO, 27 June – 1 July 2011

Outline

- “Cooling” session (Wed., 10:50–12:30)
- “SC Magnets for Cooling” session (Wed., 15:50–17:20)
- “Acceleration and Ring” session (Thurs., 10:50–12:30)

Outline

- "Cooling" session (Wed., 10:50–12:30)
- "SC Magnets for Cooling" session (Wed., 15:50–17:20)
- "Acceleration and Ring" session (Thurs., 10:50–12:30)

Caveat: Impossible to do justice to ≈5 hours' worth of talks in 15 minutes!

⇒ This is just my (necessarily subjective) impression of the highlights

“Cooling” session

“Cooling” session

1. Neuffer: Muon Capture for a Muon Collider

"Cooling" session

I. Neuffer: Muon Capture for a Muon Collider

Outline

- Motivation
  - $\mu^+ - \mu^-$ Collider front end
- Produce, collect and cool as many muons as possible
  - Start with ν–Factory IDS design study
  - Reoptimize for Collider
    - Shorter bunch train
      - Higher energy capture, shorter front-end
    - Larger gradients
- Bunch Recombiner
  - Time reverse to combine
- Beam Loss problem
  - Chicane, Absorber, shielding
- Discussion

“Cooling” session

I. Neuffer: Muon Capture for a Muon Collider

Outline

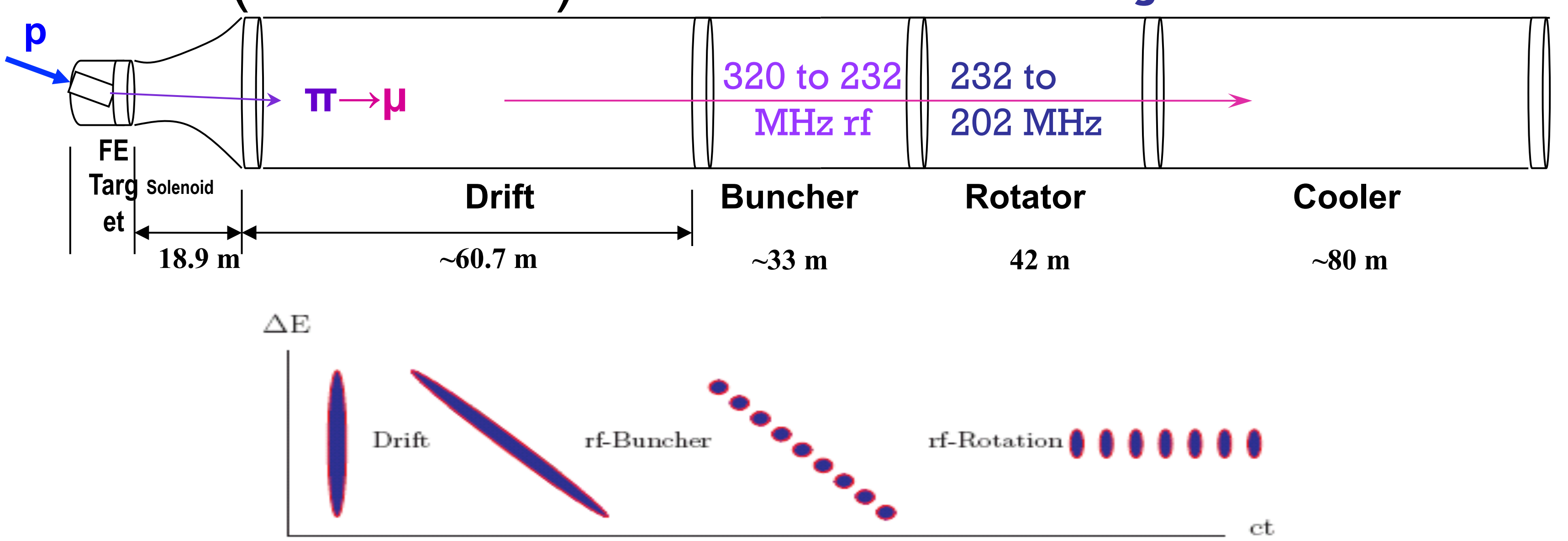
- Motivation
  - $\mu^+ - \mu^-$ Collider front end
- Produce, collect and cool as many muons as possible
  - Start with ν–Factory IDS design study
  - Reoptimize for Collider
    - Shorter bunch train
      - Higher energy capture, shorter front-end
    - Larger gradients
- Bunch Recombiner
  - Time reverse to combine
- Beam Loss problem
  - Chicane, Absorber, shielding
- Discussion

“Cooling” session

1. Neuffer: Muon Capture for a Muon Collider

- “Frequency vernier” approach:

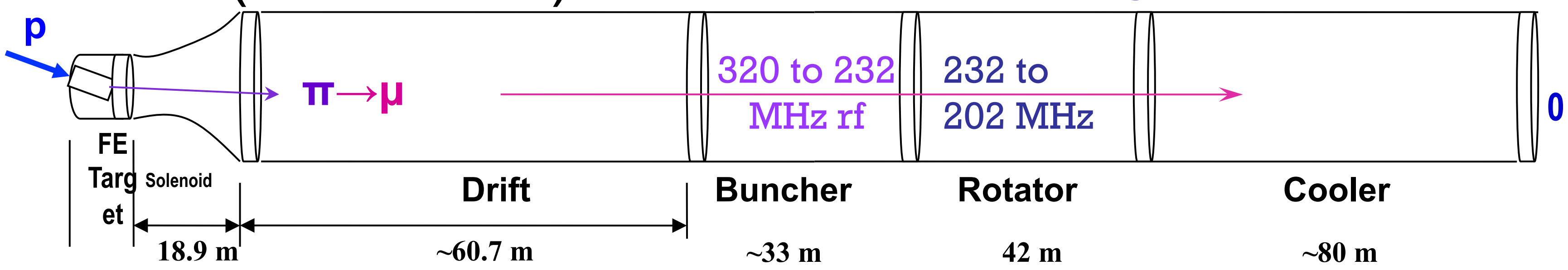
  (νF version) **Buncher momentum range: 233 to 154 MeV/c**

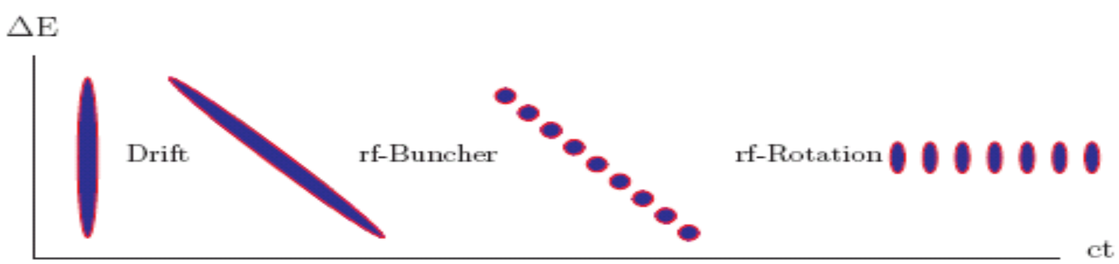


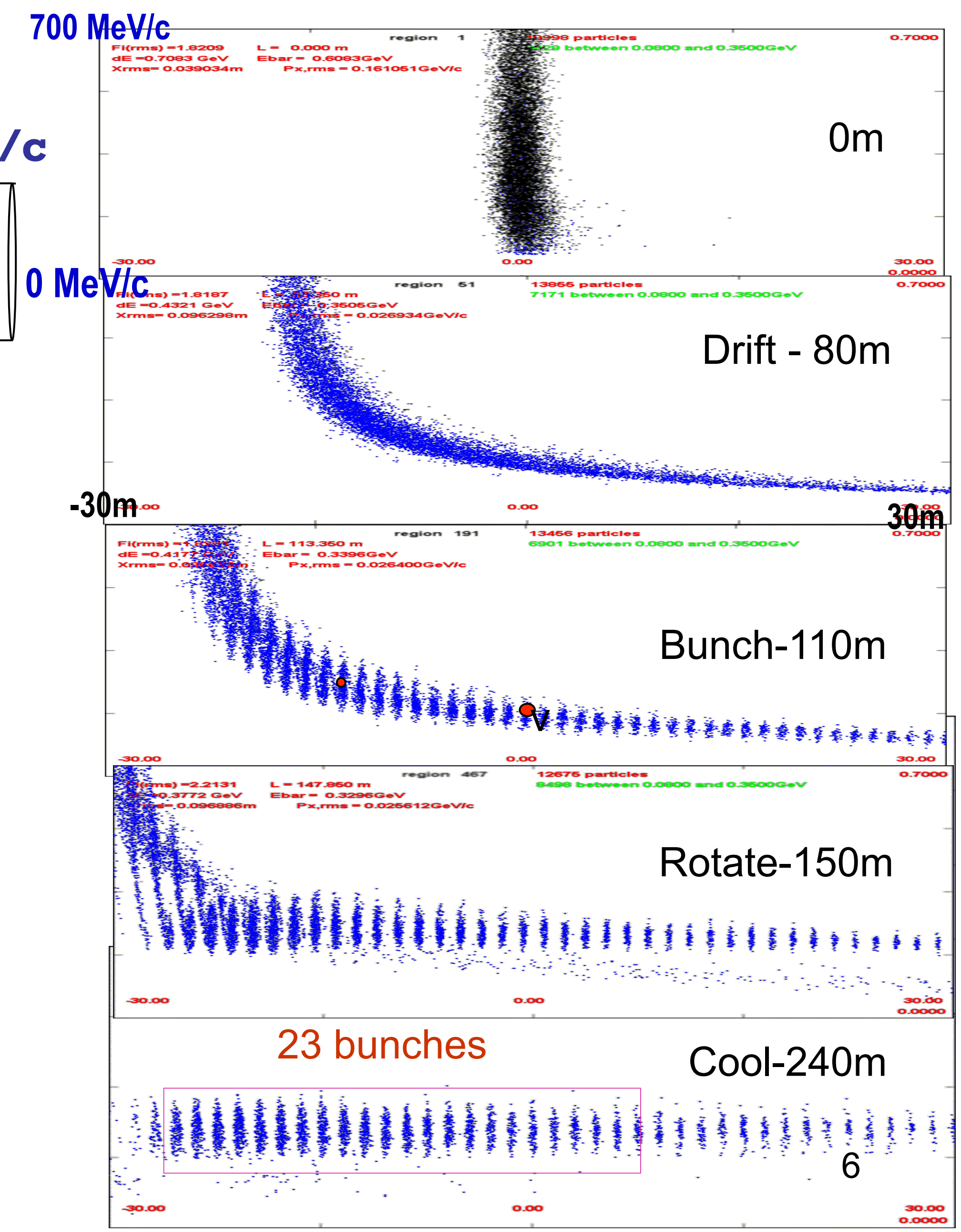
"Cooling" session

1. Neuffer: Muon Capture for a Muon Collider

- "Frequency vernier" approach:
  (νF version) **Buncher momentum range: 233 to 154 MeV/c**



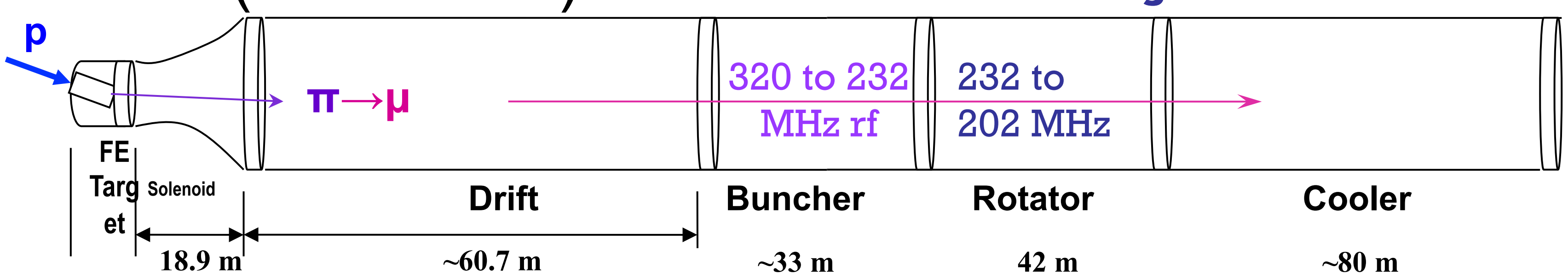




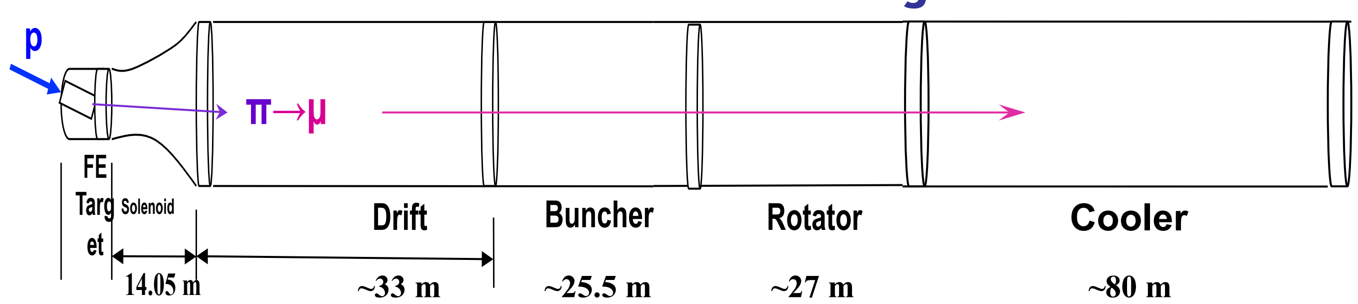
"Cooling" session

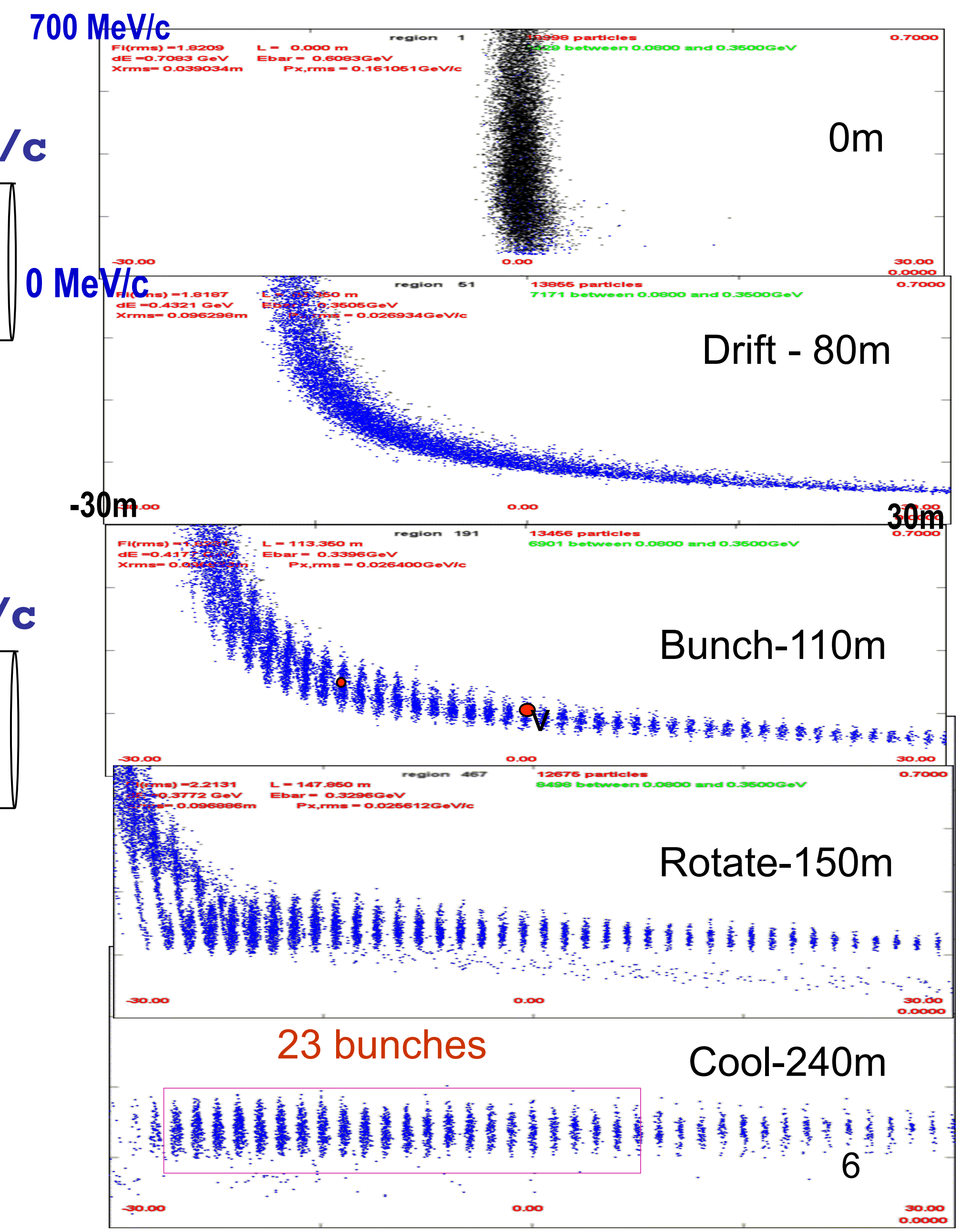
I. Neuffer: Muon Capture for a Muon Collider

- "Frequency vernier" approach:
  (νF version) **Buncher momentum range: 233 to 154 MeV/c**



- For μC, shorten & adjust vernier:
  Raise momentum range: 233→275 MeV/c

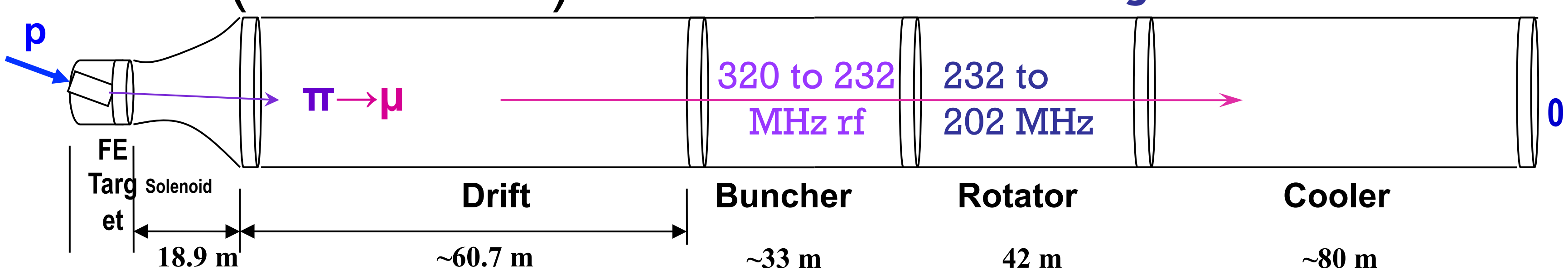




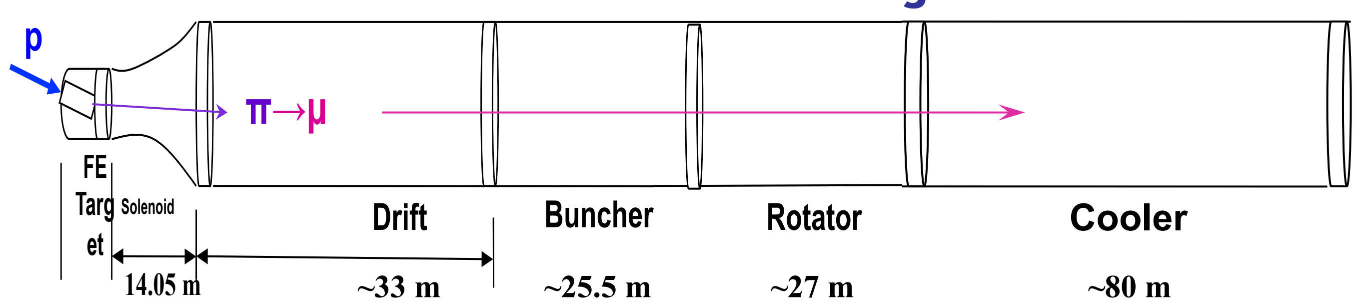
“Cooling” session

1. Neuffer: Muon Capture for a Muon Collider

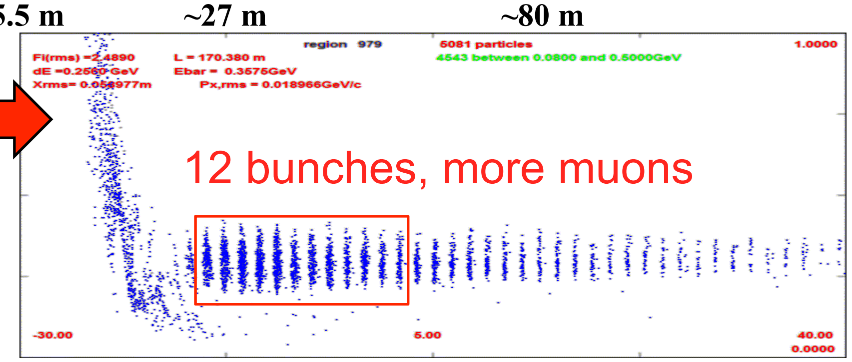
- “Frequency vernier” approach:
  (νF version) **Buncher momentum range: 233 to 154 MeV/c**

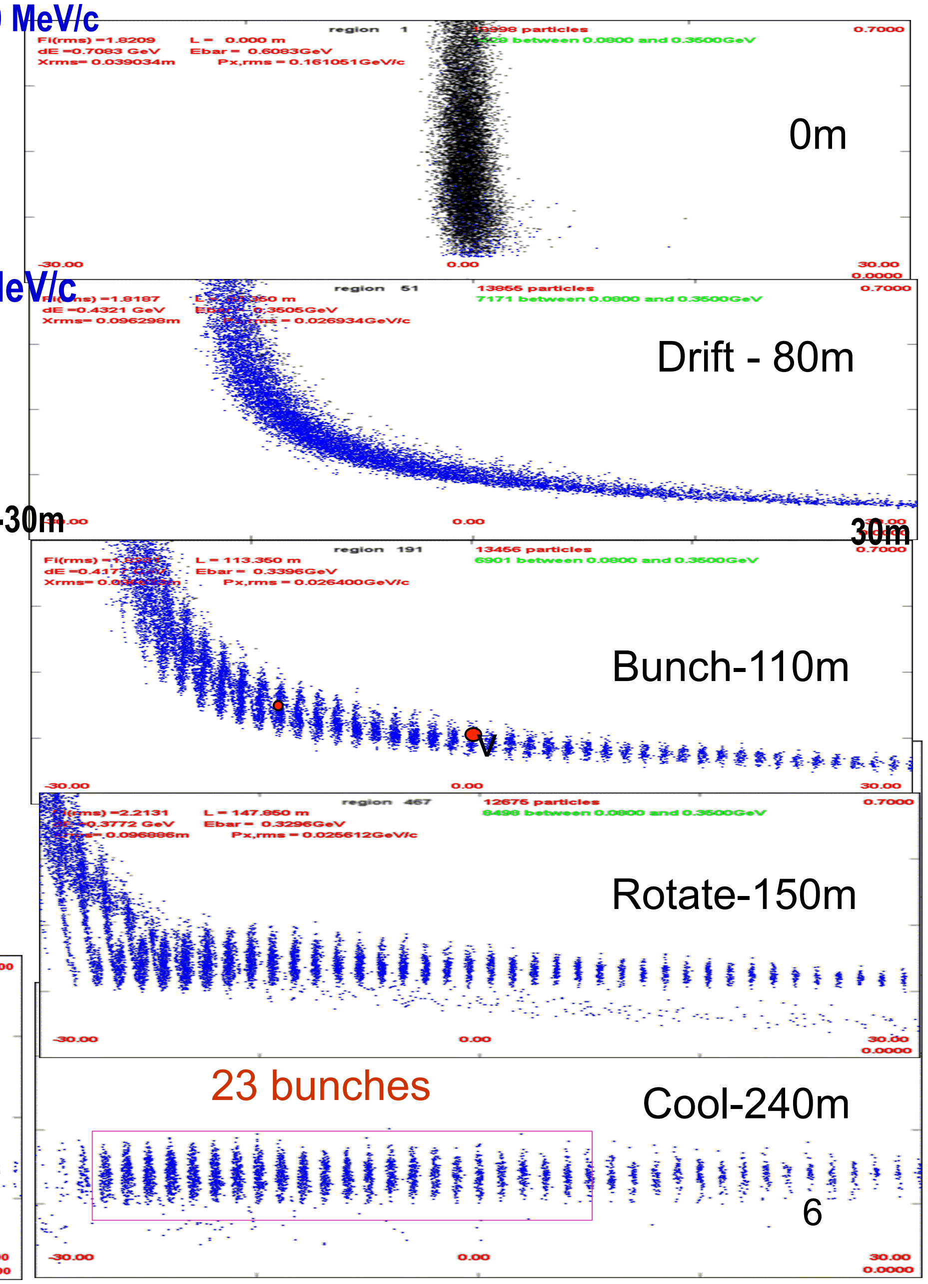


- For μC, shorten & adjust vernier:
  Raise momentum range: 233→275 MeV/c



- Better for bunch recombination

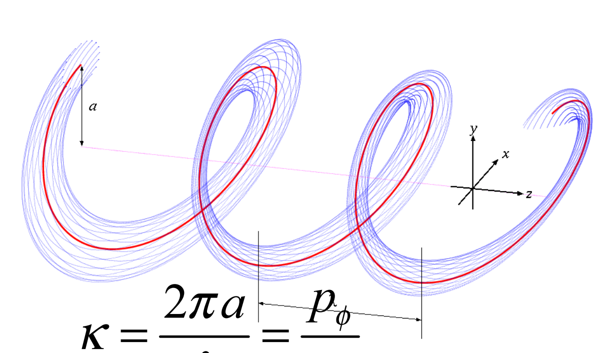




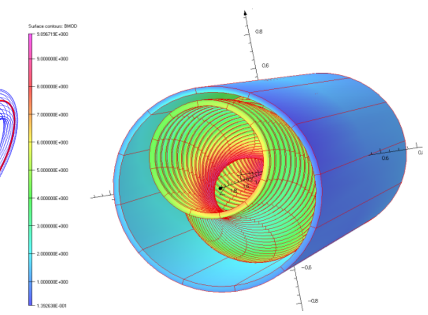
“Cooling” session

1. Neuffer: Muon Capture for a Muon Collider

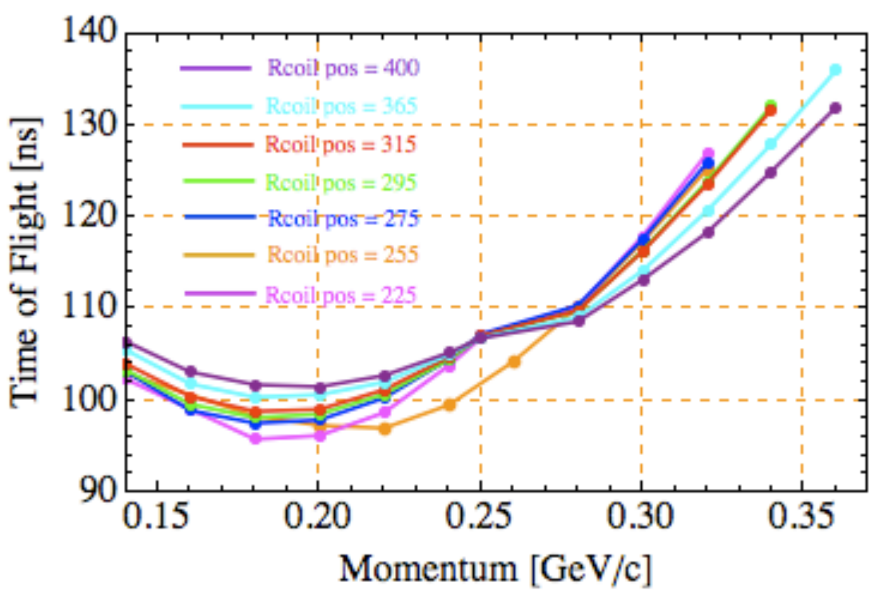
- Also discussed:
  helical bunch recombiner
- Linear time-momentum relation attractive for bunch recombination:



$$\kappa = \frac{2\pi a}{\lambda} = \frac{p_\phi}{p_z}$$



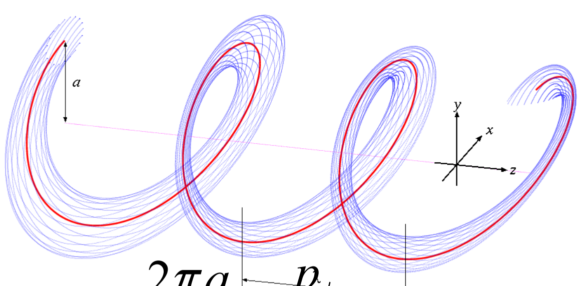
$$\delta t = \eta \frac{\Delta E}{mc^2}$$



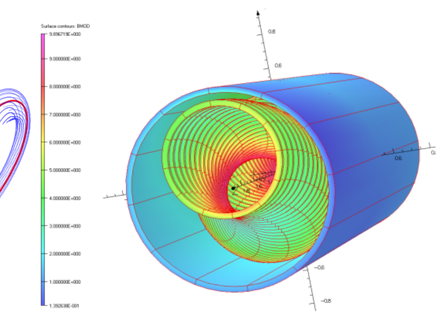
“Cooling” session

1. Neuffer: Muon Capture for a Muon Collider

- Also discussed:
  helical bunch recombiner

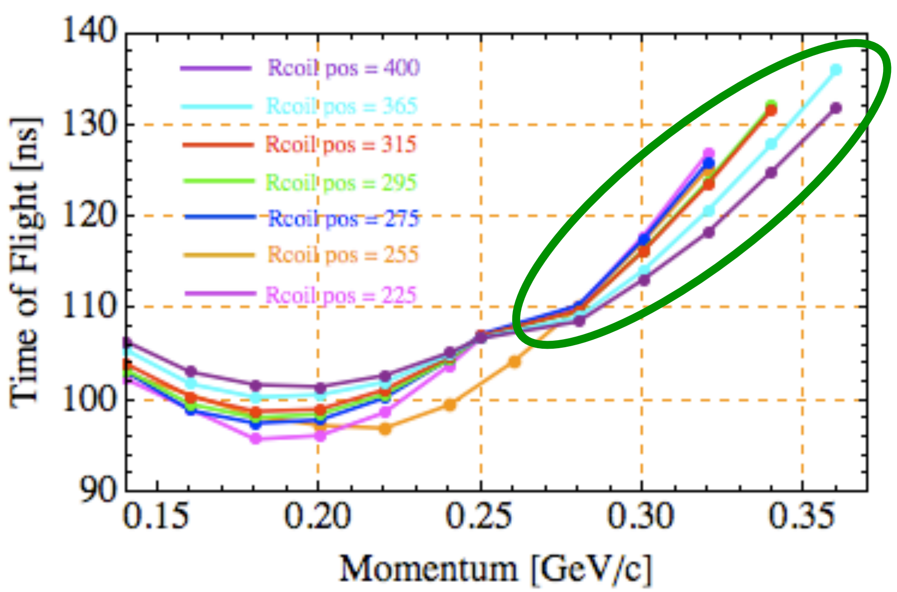


$$\kappa = \frac{2\pi a}{\lambda} = \frac{p_\phi}{p_z}$$



$$\delta t = \eta \frac{\Delta E}{mc^2}$$

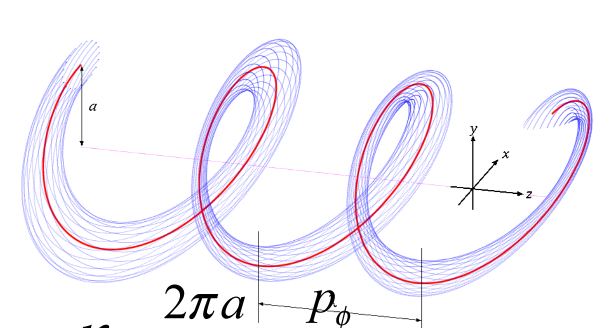
- Linear time-momentum relation attractive for bunch recombination:



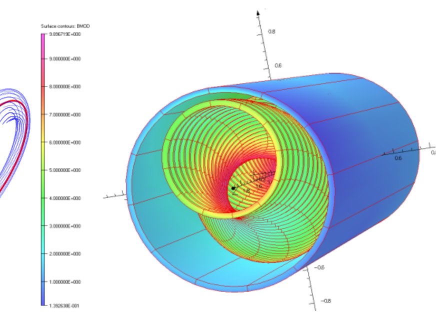
“Cooling” session

1. Neuffer: Muon Capture for a Muon Collider

- Also discussed:
  helical bunch recombiner

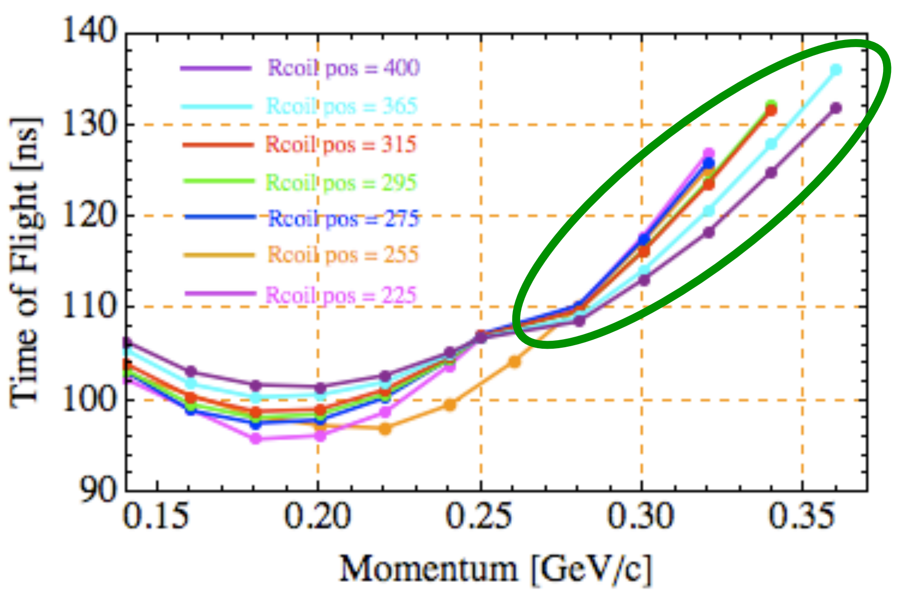


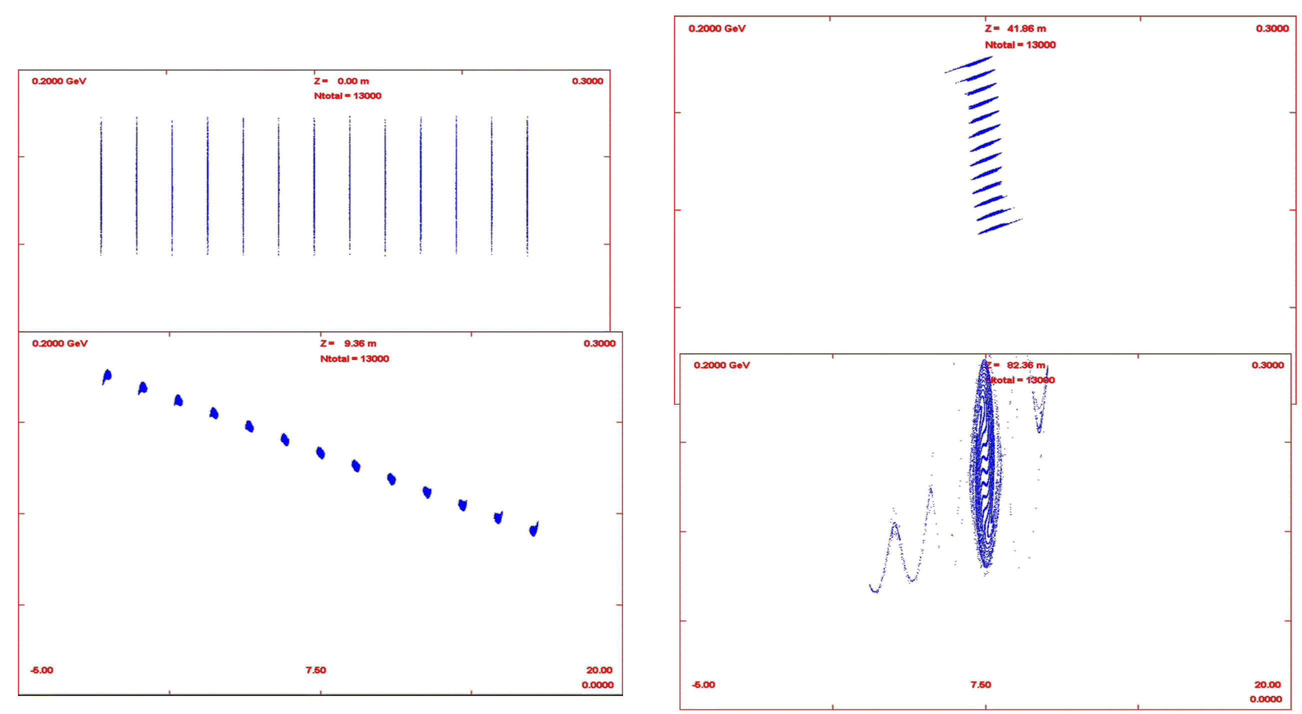
$$\kappa = \frac{2\pi a}{\lambda} = \frac{p_\phi}{p_z}$$



$$\delta t = \eta \frac{\Delta E}{mc^2}$$

- Linear time-momentum relation attractive for bunch recombination:

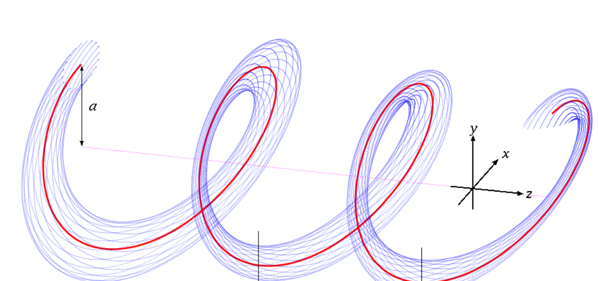


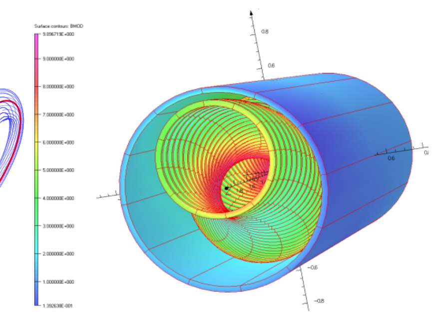


“Cooling” session

1. Neuffer: Muon Capture for a Muon Collider

- Also discussed:
  helical bunch recombiner

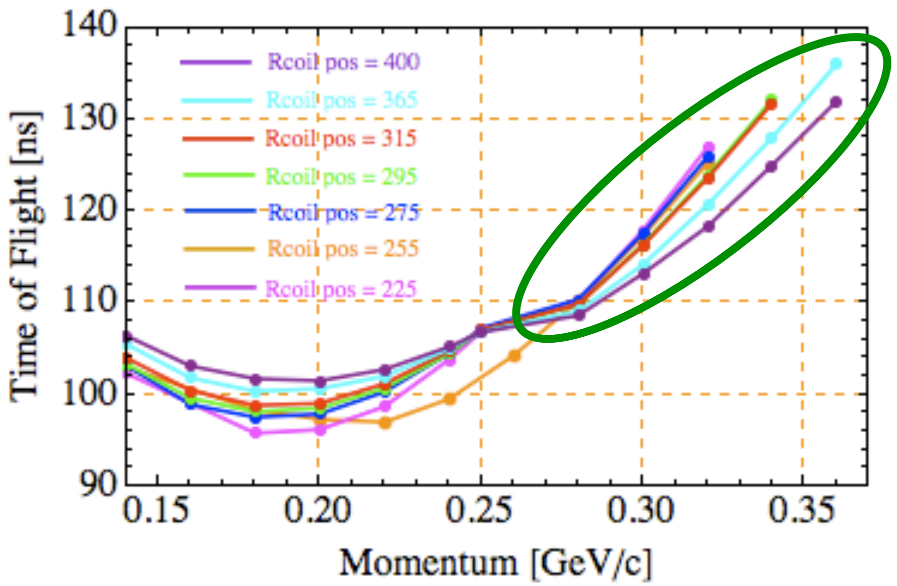


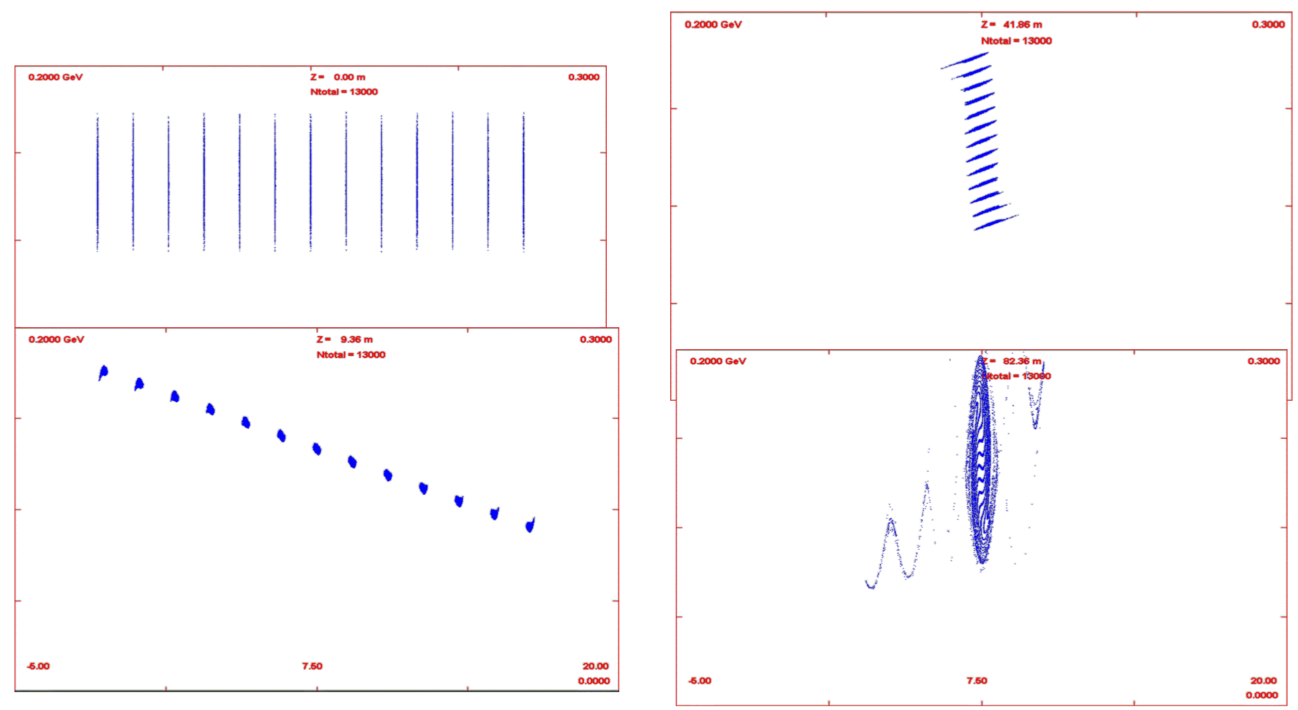


$$\kappa = \frac{2\pi a}{\lambda} = \frac{p_\phi}{p_z}$$

$$\delta t = \eta \frac{\Delta E}{mc^2}$$

- Linear time-momentum relation attractive for bunch recombination:





- See his talk for much more!

“Cooling” session

2. Roberts: <u>Cooling</u>

"Cooling" session

2. Roberts: Cooling

Muons, Inc.

Outline

- Muon Ionization Cooling
  - Everything you need to know in 30 seconds
- The Devil is in the Details
  - Brief Descriptions of 6-D Cooling Techniques
  - Brief Descriptions of Final Cooling Techniques
  - Briefer Descriptions of Other Techniques
- God is in the Details
  - Putting It All Together
  - System-Level Considerations
- The Details are in the Details
  - MAP Cooling Efforts in the Next Year or So
- Summary

"Cooling" session

2. Roberts: Cooling

Muons, Inc.

Summary

- Muon Ionizati
  - Everything y
- The Devil is ir
  - Brief Descrip
  - Brief Descrip
  - Briefer Desc
- God is in the
  - Putting It All
  - System-Leve
- The Details a
  - MAP Cooling
- Summary

- We have mature conceptual designs for three 6-D cooling techniques:
  - **Guggenheim**
  - **Helical Cooling Channel**
  - **FOFO Snake**
- We have a mature conceptual design for one final cooling technique, albeit with serious challenges:
  - **High-field solenoids**
- We have a good start on a promising new final cooling technique:
  - **Epicyclic PIC**
- We have a good start on the additional components.
- We need to perform complete simulations of every component, including matching.

The details are daunting, and there is a lot of work remaining to prepare for the cooling down-selection.

“Cooling” session

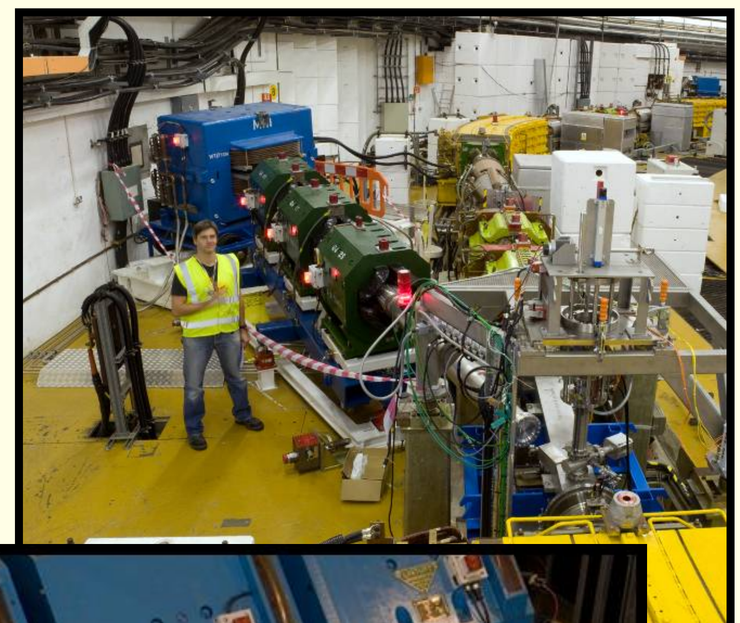
3. Coney: MICE

“Cooling” session

3. Coney: MICE

Outline

- *Introduction*
- *MICE Description*
- *Step 1 Results*
- *Cooling Channel Status*
- *Conclusions*



"Cooling" session

3. Coney: MICE

Outline

- *Introduction*
- *MICE Description*
- *Step 1 Results*
- *Cooling Channel Status*
- *Conclusions*

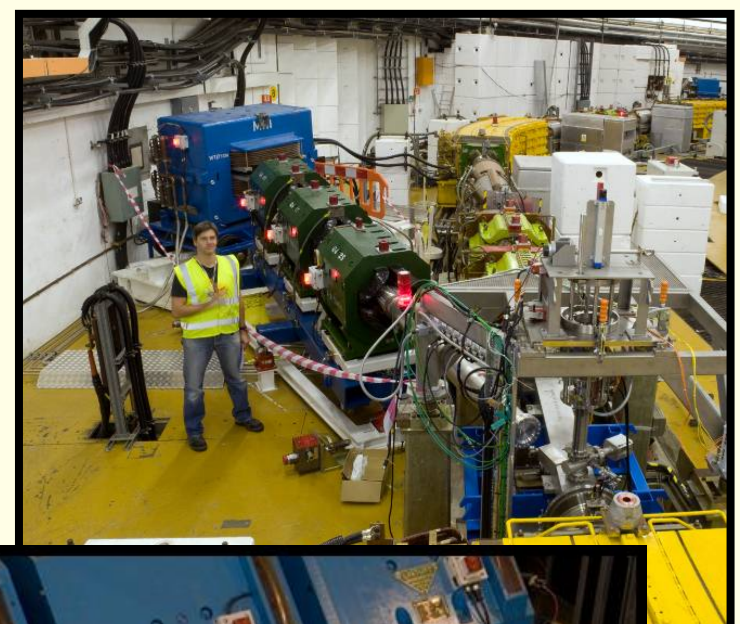
Conclusions:

"Cooling" session

3. Coney: MICE

Outline

- *Introduction*
- *MICE Description*
- *Step 1 Results*
- *Cooling Channel Status*
- *Conclusions*



Conclusions:

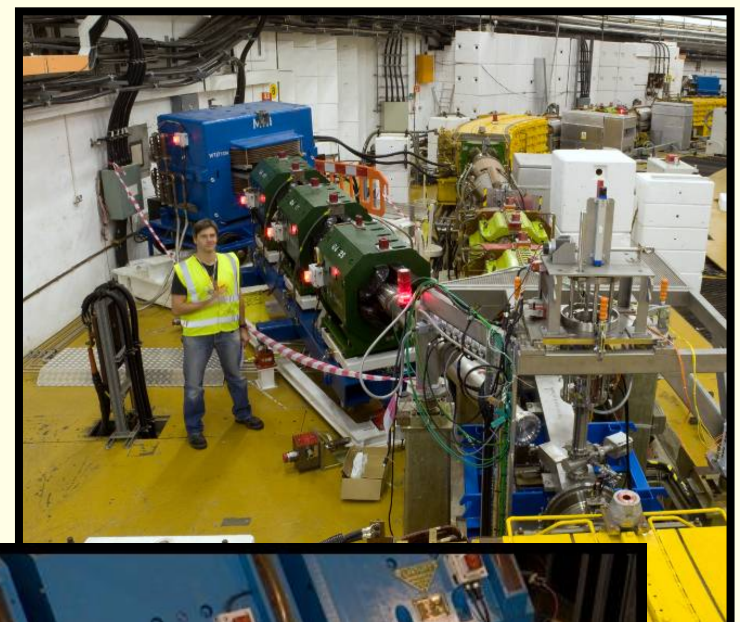
- MICE Step 1 data-taking complete

"Cooling" session

3. Coney: MICE

Outline

- *Introduction*
- ***MICE Description***
- ***Step 1 Results***
- ***Cooling Channel Status***
- ***Conclusions***



Conclusions:

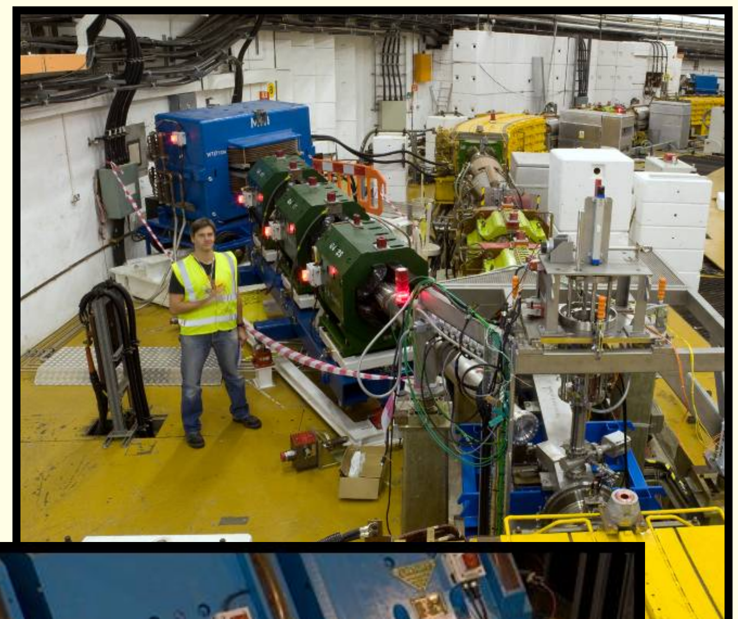
- **MICE Step 1 data-taking complete**
- ***Innovation*: while awaiting spectrometer solenoids, measured beam emittance using time-of-flight detectors alone!**

"Cooling" session

3. Coney: MICE

Outline

- *Introduction*
- *MICE Description*
- *Step 1 Results*
- *Cooling Channel Status*
- *Conclusions*



Conclusions:

- **MICE Step 1 data-taking complete**
- ***Innovation*: while awaiting spectrometer solenoids, measured beam emittance using time-of-flight detectors alone!**
- **MICE muon beam understood and ready for arrival of spectrometer solenoids and cooling channel**

"SC Magnets for Cooling" session

“SC Magnets for Cooling” session

I. Ogitsu: Radiation Hardness of LTS and HTS SC

"SC Magnets for Cooling" session

I. Ogitsu: Radiation Hardness of LTS and HTS SC

Contents

- Why KEK (J-PARC cryogenics section) is studying Radiation Resistant SC Magnets
- Radiation Hardness of SC Magnet
- Present R&D and Future Plan
- Summary

Needed for JPARC high-power SuperΩ and COMET muon facilities

"SC Magnets for Cooling" session

I. Ogitsu: Radiation Hardness of LTS and HTS SC

Contents

- Why KEK (J-PARC cryogenics section) is studying Radiation Resistant SC Magnets
- Radiation Hardness of SC Magnet
- Present R&D and Future Plan
- Summary:

Needed for JPARC high-power SuperΩ and COMET muon facilities

“SC Magnets for Cooling” session

I. Ogitsu: Radiation Hardness of LTS and HTS SC

Contents

- Why KEK (J-PARC cryogenics section) is studying Radiation Resistant SC Magnets
- Radiation Hardness of SC Magnet
- Present R&D and Future Plan
- Summary:

Needed for JPARC high-power SuperΩ and COMET muon facilities

> – Literature indicates NbTi, Nb_3Sn, YBCO all OK up to 10^{22} n/m^2
> – Irradiation studies done on Al, Cu stabilizers
> – Tentative design guideline: 10^{22} n/m^2, 10 MGy. (≅ITER spec.)
> – Current R&D priority: Stabilizers and Glues
> – Thermal cycle to room temperature may help to recover properties of metals, but not organic materials

"SC Magnets for Cooling" session

2. Shen: Generating Very High Magnetic Field using a round–wire HTS conductor & Quench protection of HTS magnets

"SC Magnets for Cooling" session

2. Shen: Generating Very High Magnetic Field using…

Muon collider designs demand 30-50 T solenoids

NMR communities need 30 T all superconducting magnets.

- **A transformational opportunity for high-field science**
  - But it is also a quantum leap in technology.
- **Challenges to 30+ T HTS magnets:**
  - Engineering the conductor to carry >200 A/mm^2 in 20-50 T
  - Managing stress >200 MPa
  - Protecting magnet from quenches
- **We recently significantly improved the J_e of a round-wire HTS conductor to 600 A/mm^2 at 4.2 K, 20 T.**
- **Quench is an old problem but needs new solution in HTS magnets**
  - Finding a novel quench detection method is the key.

ILLINOIS INSTITUTE OF TECHNOLOGY
Transforming Lives.Inventing the Future.www.iit.edu

"SC Magnets for Cooling" session

Muon Accelerator Program

2. Shen: Generating Very High Magnetic Field using…

Muon collider designs demand 30-50 T solenoids

NMR communities need 30 T all superconducting magnets.

- **A transformational opportunity for high-field science** ➡ **VHFSMC**
  - But it is also a quantum leap in technology.
- **Challenges to 30+ T HTS magnets:**
  - Engineering the conductor to carry >200 A/mm² in 20-50 T
  - Managing stress >200 MPa
  - Protecting magnet from quenches
- **We recently significantly improved the J_e of a round-wire HTS conductor to 600 A/mm² at 4.2 K, 20 T.**
- **Quench is an old problem but needs new solution in HTS magnets**
  - Finding a novel quench detection method is the key.

"SC Magnets for Cooling" session

2. Shen: Generating Very High Magnetic Field using…

Muon collider designs demand 30-50 T solenoids

NMR communities need 30 T all superconducting magnets.

- **A transformational opportunity for high-field science** ➡ **VHFSMC**
  - But it is also a quantum leap in technology.
- **Challenges to 30+ T HTS magnets:**
  - Engineering the conductor to carry >200 A/mm² in 20-50 T
  - Managing stress >200 MPa
  - Protecting magnet from quenches
- **We recently significantly improved the J_e of a round-wire HTS conductor to 600 A/mm² at 4.2 K, 20 T.** ^ **BSCCO**
- **Quench is an old problem but needs new solution in HTS magnets**
  - Finding a novel quench detection method is the key.

"SC Magnets for Cooling" session

2. Shen: Generating Very High Magnetic Field using…

Muon collider designs demand 30-50 T solenoids

NMR communities need 30 T all superconducting magnets.

- **A transformational opportunity for high-field science** ➡ **VHFSMC**
  - But it is also a quantum leap in technology.
- **Challenges to 30+ T HTS magnets:**
  - Engineering the conductor to carry >200 A/mm² in 20-50 T
  - Managing stress >200 MPa
  - Protecting magnet from quenches
- **We recently significantly improved the J_e of a round-wire HTS conductor to 600 A/mm² at 4.2 K, 20 T.** **BSCCO** **^**
- **Quench is an old problem but needs new solution in HTS magnets**
  - Finding a novel quench detection method is the key.

"SC Magnets for Cooling" session

3. Gupta: R&D Towards 40T Solenoids at BNL

"SC Magnets for Cooling" session

3. Gupta: R&D Towards 40T Solenoids at BNL

BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division

High Field Solenoid Projects at BNL

- ~35 T HTS/Nb_3Sn s.c. solenoid for Muon Collider (PBL/BNL SBIRs)
  - 34 HTS coils already built and tested using over 3 km of conductor
- ~40T (~20^+T HTS) insert coil PBL/BNL SBIR (~20^+T comes from HTS)
  - 23 T already demonstrated in the background field of NHMFL
- ~25 T large aperture HTS solenoid for SMES (ARPA-E funded)
  - R&D would directly benefit high field solenoids for SMES
- A very brief summary of selected HTS R&D on related topics (e.g. quench protection, stress limit, radiation damage) and other HTS programs at BNL

"SC Magnets for Cooling" session

3. Gupta: R&D Towards 40T Solenoids at BNL

BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division

High Field Solenoid Projects at BNL

- ~35 T HTS/Nb_3Sn s.c. solenoid for Muon Collider (PBL/BNL SBIRs)
  - 34 HTS coils already built and tested using over 3 km of conductor
- ~40T (~20^+T HTS) insert coil PBL/BNL SBIR (~20^+T comes from HTS)
  - 23 T already demonstrated in the background field of NHMFL
- ~25 T large aperture HTS solenoid for SMES (ARPA-E funded)
  - R&D would directly benefit high field solenoids for SMES
- A very brief summary of selected HTS R&D on related topics (e.g. quench protection, stress limit, radiation damage) and other HTS programs at BNL

“SC Magnets for Cooling” session

3. Gupta: R&D Towards 40T Solenoids at BNL

BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division

High Field Solenoid Projects at BNL

- ~35 T HTS/Nb_3S ... BNL SBIRs)
  - 34 HTS ... 3 km of conductor
- ~40T (~20^+T HT ... mes from HTS)
  - 23 T al ... eld of NHMFL

YBCO

- ~25 T large aperture HTS solenoid for SMES (ARPA-E funded)
  - R&D would directly benefit high field solenoids for SMES
- A very brief summary of selected HTS R&D on related topics (e.g. quench protection, stress limit, radiation damage) and other HTS programs at BNL

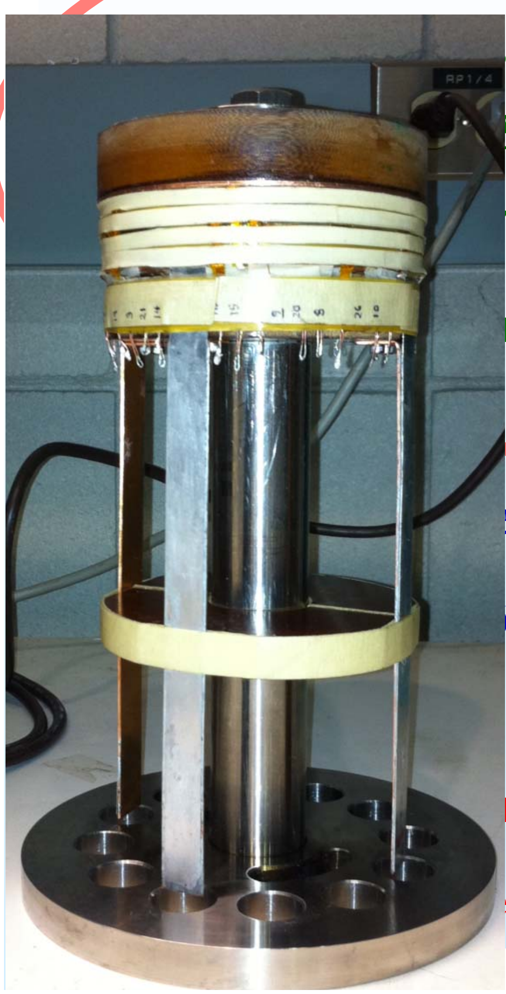
ILLINOIS INSTITUTE OF TECHNOLOGY
Transforming Lives.Inventing the Future.www.iit.edu

"SC Magnets for Cooling" session

3. Gupta: R&D Towards 40T Solenoids at BNL

BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division

High Field Solenoid Projects at BNL



BNL SBIRs)

3 km of conductor

mes from HTS)

eld of NHMFL

YBCO

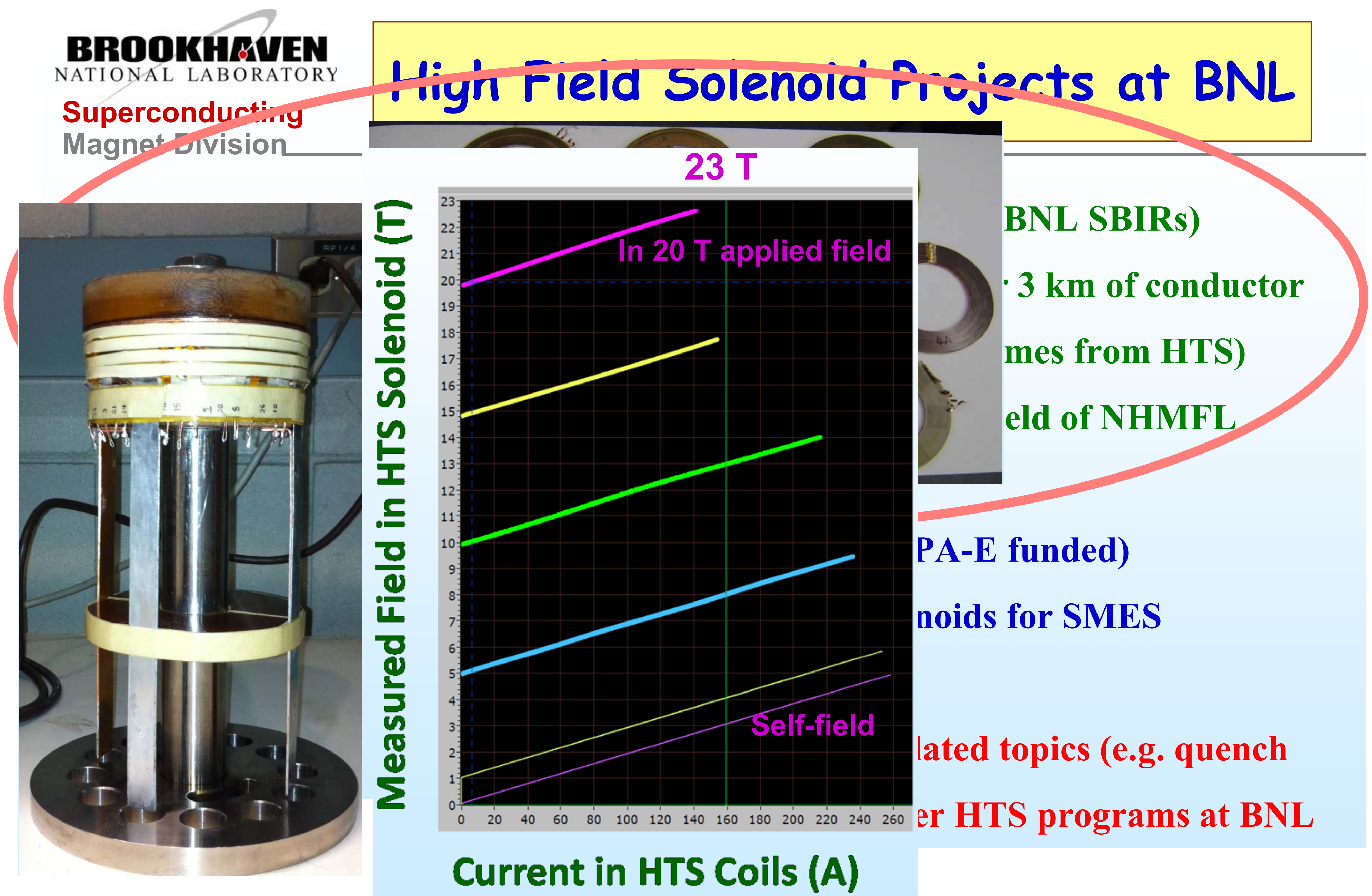
erture HTS solenoid for SMES (ARPA-E funded)

vould directly benefit high field solenoids for SMES

mmary of selected HTS R&D on related topics (e.g. quench

ss limit, radiation damage) and other HTS programs at BNL

3. Gupta: R&D Towards 40T Solenoids at BNL



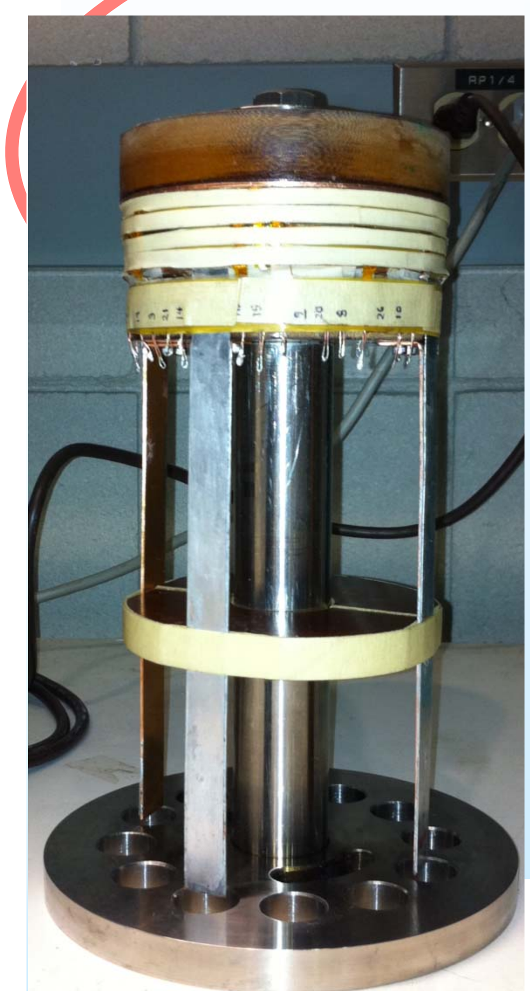
"SC Magnets for Cooling" session

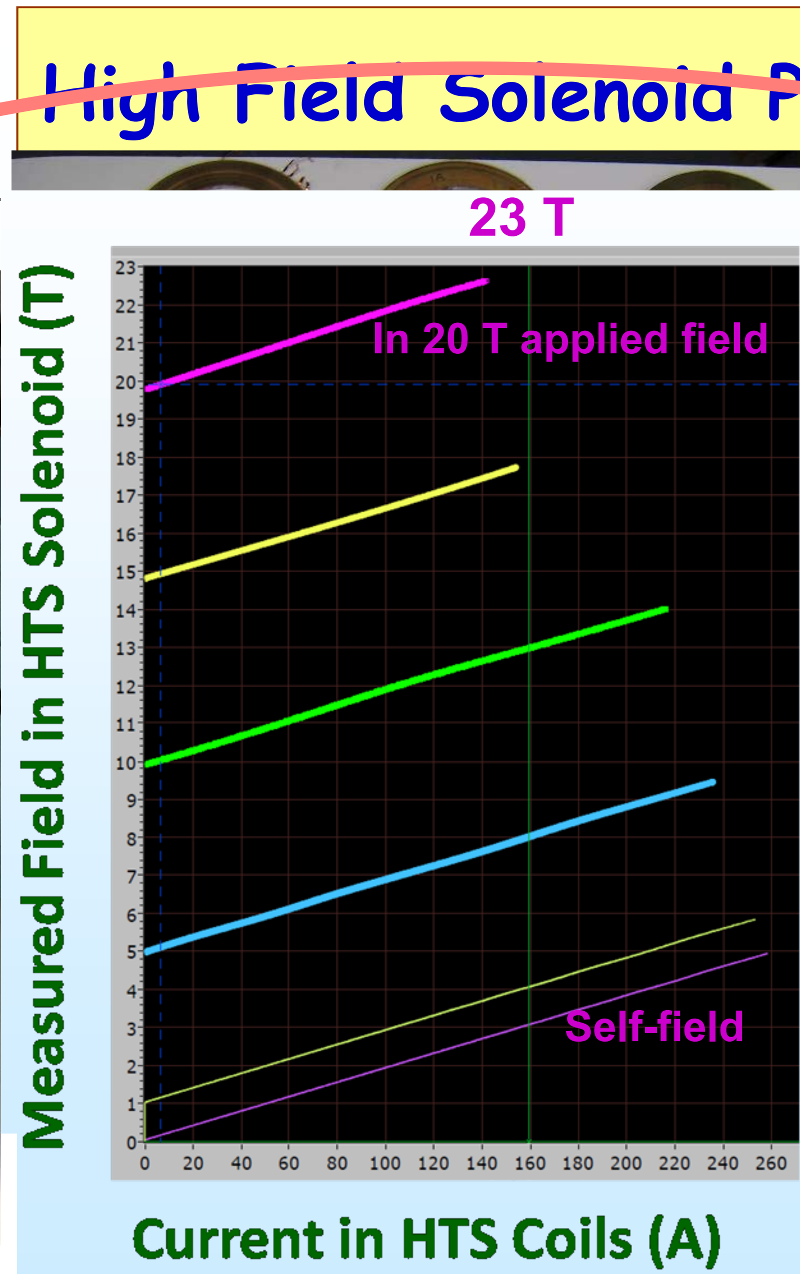
ILLINOIS INSTITUTE OF TECHNOLOGY
Transforming Lives. Inventing the Future. www.iit.edu

Muon Accelerator Program

3. Gupta: R&D Towards 40T Solenoids at BNL

BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division





- We hope to demonstrate a ~100 mm, 10 T HTS solenoid in a few months.
- We hope to demonstrate 10-12 T, ~25 mm insert HTS solenoid in ~6 month.
- We hope to demonstrate ~20-22 T HTS solenoid by combining two in ~10 month.
- We hope to test above in ~20 T resistive solenoid at NHMFL to test HTS magnet technology to field approaching 40 T in about a year or so.

- Novel HTS quench protection R&D under way

- Vigorous R&D program with funding from many sources: SBIRs, FRIB, ARPA-E (SMES), base program,...
- MAP invited to collaborate more closely

“SC Magnets for Cooling” session

4. Lombardo: R&D Towards 40T Solenoids at FNAL

4. Lombardo: R&D Towards 40T Solenoids at FNAL

Talk Outline

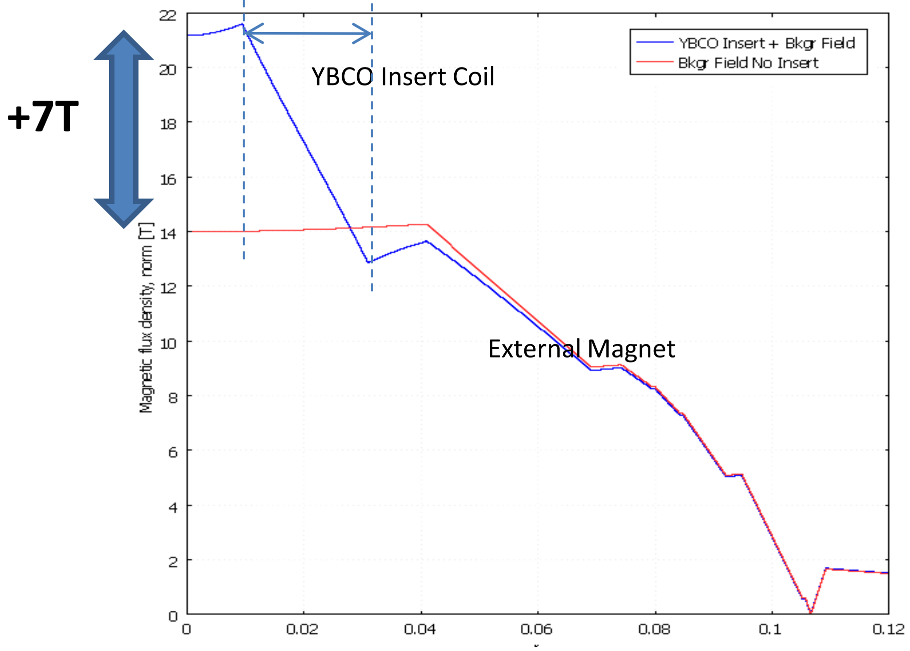
1. YBCO Coated Conductors
2. YBCO Insert Coils for High Field Magnets
   1. Overview of Manufacturing and Testing of YBCO insert coils
   2. How to account for anisotropy in YBCO magnet design both for self field and in-field operation
   3. Overview of Single and multi-pancake coil assembly
   4. Short sample predictions and test results at 77K and 4.2K at field
   5. High Current YBCO Cables?
3. YBCO Helical Solenoid Coils
   1. Overview of technology
   2. Challenges
4. Conclusions

"SC Magnets for Cooling" session

4. Lombardo: R&D Towards 40T Solenoids at FNAL

Talk Outline

1. YBCO Coated Conductors
2. YBCO Insert Coils for High Field Magnets
   1. Overview of Manufacturing and Testing of YBCO insert coils
   2. How to account for anisotropy in YBCO magnet design both for self field and in-field operation
   3. Overview of Single and multi-pancake coil assembly
   4. Short sample predictions and test results at 77K and 4.2K at field
   5. High Current YBCO Cables?
3. YBCO Helical Solenoid Coils
   1. Overview of technology
   2. Challenges
4. Conclusions

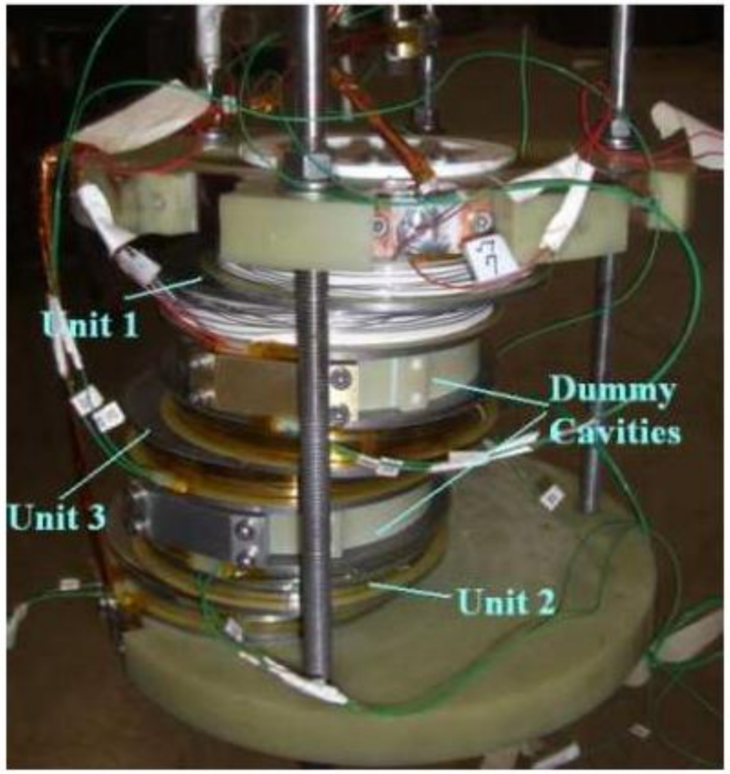


“SC Magnets for Cooling” session

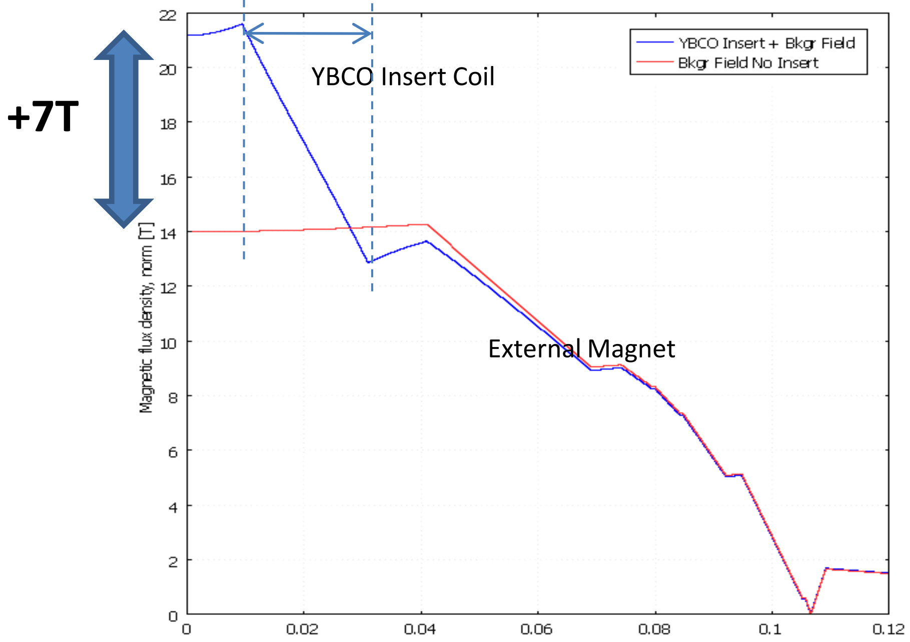
4. Lombardo: R&D Towards 40T Solenoids at FNAL

Talk Outline

1. YBCO Coated Conductors
2. YBCO Insert Coils for High Field Magnets
   1. Overview of Manufacturing and Testing of YB
   2. How to account for anisotropy in YBCO magn
   3. Overview of Single and multi-pancake coil ass
   4. Short sample predictions and test results at 7
   5. High Current YBCO Cables?
3. YBCO Helical Solenoid Coils
   1. Overview of technology
   2. Challenges
4. Conclusions



M. Yu et al. “Fabrication and test of short helical solenoid model based on ybco tape”



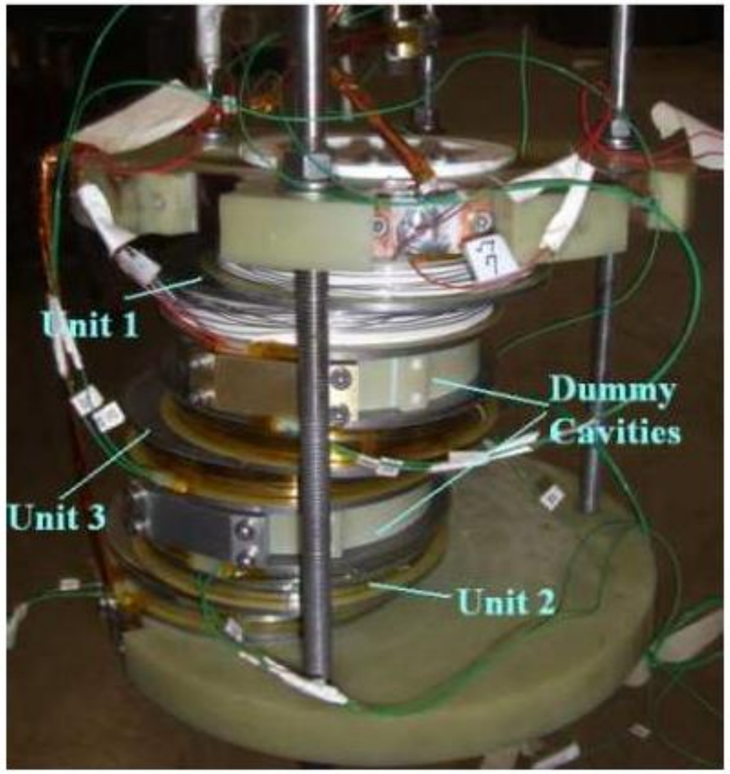
"SC Magnets for Cooling" session

4. Lombardo: R&D Towards 40T Solenoids at FNAL

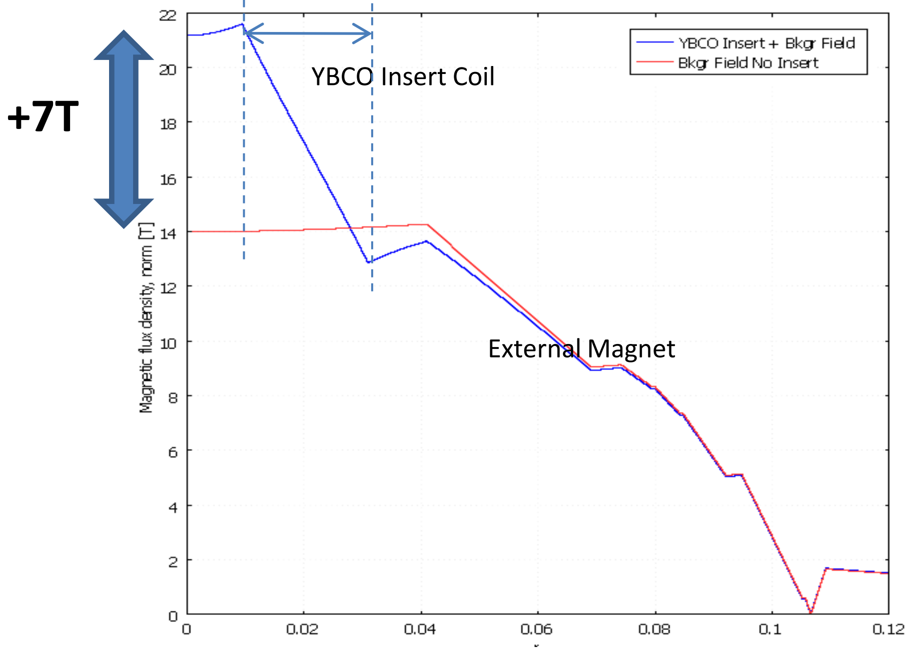
Talk Outline

1. YBCO Coated Conductors
2. YBCO Insert Coils for High Field Magnets
    1. Overview of Manufacturing and Testing of YB
    2. How to account for anisotropy in YBCO magn
    3. Overview of Single and multi-pancake coil ass
    4. Short sample predictions and test results at 7
    5. High Current YBCO Cables?
3. YBCO Helical Solenoid Coils
    1. Overview of technology
    2. Challenges
4. Conclusions

"30-40T fully superconducting magnets are achievable with technology available today."



M. Yu et al. "Fabrication and test of short helical solenoid model based on ybco tape"



“Acceleration and Ring” session

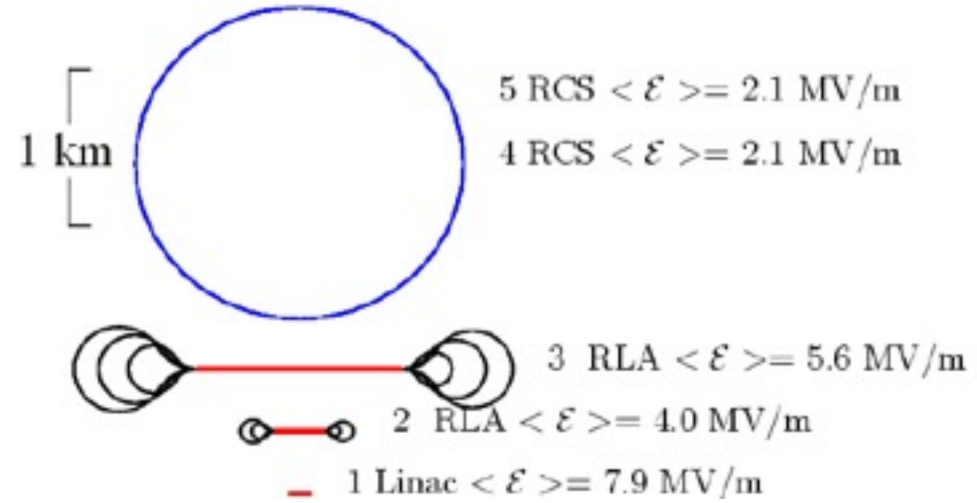
“Acceleration and Ring” session

1. Bogacz: Acceleration

"Acceleration and Ring" session

1. Bogacz: Acceleration

- Progress reoptimizing acceleration for μC (as opposed to νF)

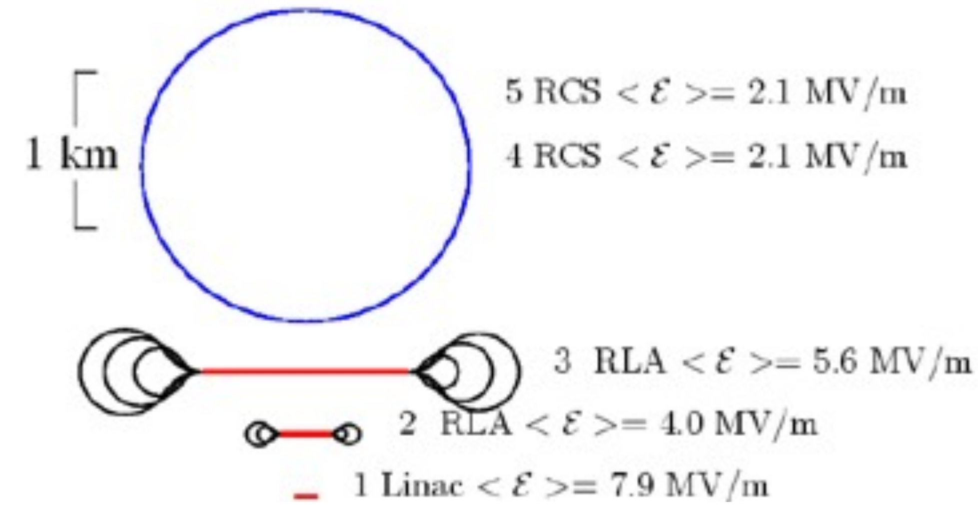


	E_f GeV	n	f_{RF} MHz	V_{avg} MV/m	Decay %	P_{pk} MW	P_{wall} MW
Linac	1.5	1.0	201	7.9	2.4	46	3.4
RLA	12.5	**4.5**	201	4.0	7.6	105	7.8
RLA	100.0	6.5	402	5.6	5.4	469	11.7
RCS	400.0	23.0	805	2.1	10.2	396	4.7
RCS	750.0	27.0	805	2.1	4.8	393	7.2
					27.1		34.8

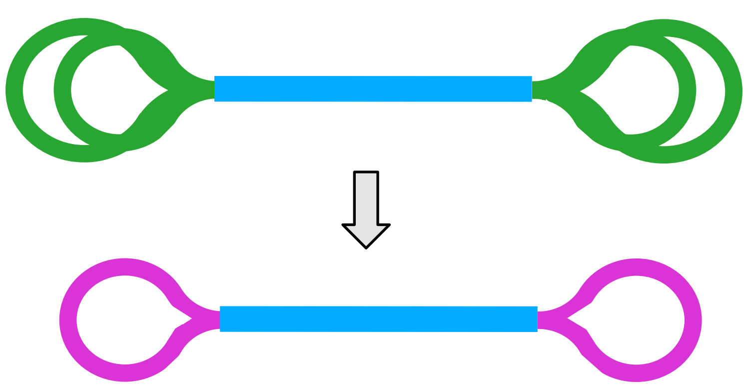
"Acceleration and Ring" session

1. Bogacz: Acceleration

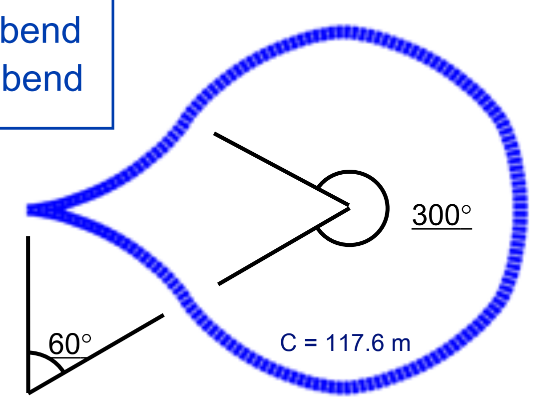
- Progress reoptimizing acceleration for μC (as opposed to νF)
- Now exploring dogbone RLAs with multipass arcs (design for 2 energies)

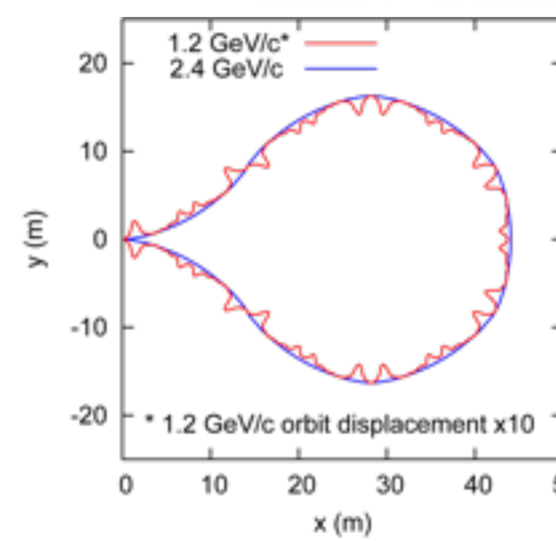


	E_f GeV	n	f_{RF} MHz	V_{avg} MV/m	Decay %	P_{pk} MW	P_{wall} MW
Linac	1.5	1.0	201	7.9	2.4	46	3.4
RLA	12.5	**4.5**	201	4.0	7.6	105	7.8
RLA	100.0	6.5	402	5.6	5.4	469	11.7
RCS	400.0	23.0	805	2.1	10.2	396	4.7
RCS	750.0	27.0	805	2.1	4.8	393	7.2
					27.1		34.8



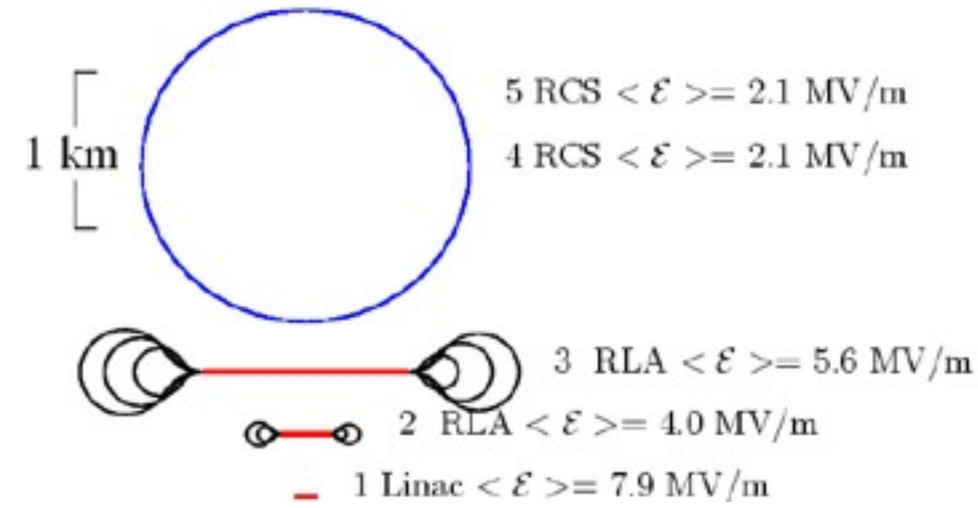
Droplet arc:
- 60° outward bend
- 300° inward bend
- 60° outward bend





“Acceleration and Ring” session

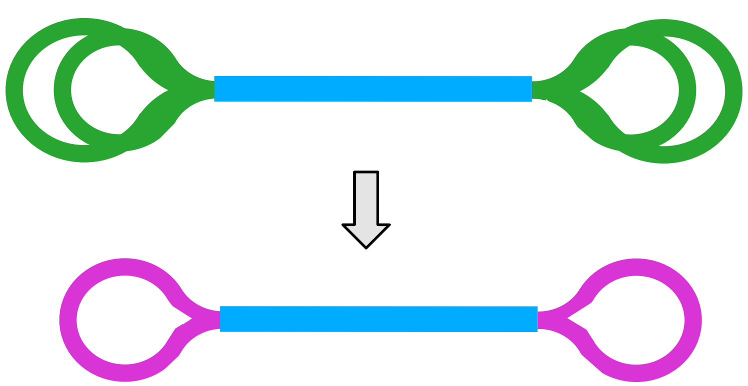
I. Bogacz: Acceleration



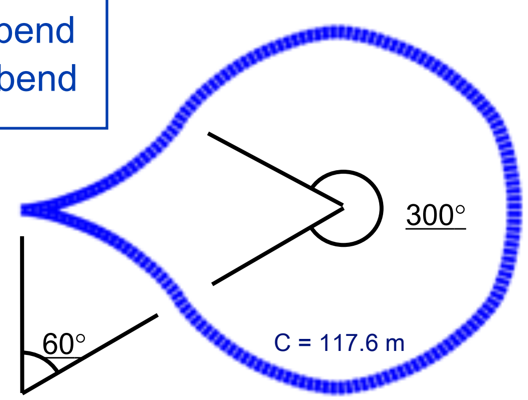
- Progress reoptimizing acceleration for μC (as opposed to νF)

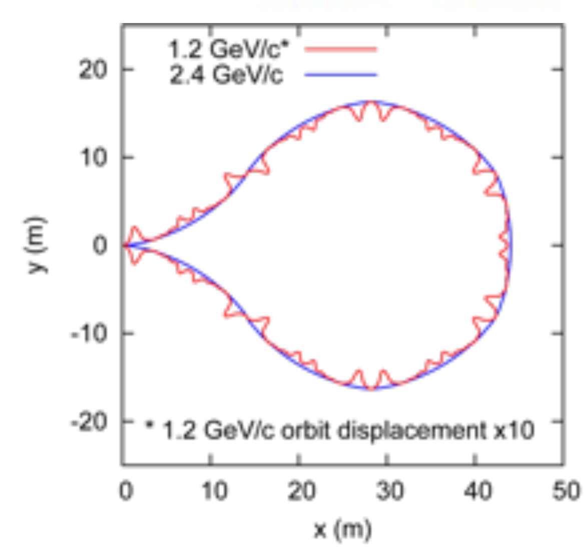
	E_f GeV	n	f_{RF} MHz	V_{avg} MV/m	Decay %	P_{pk} MW	P_{wall} MW
Linac	1.5	1.0	201	7.9	2.4	46	3.4
RLA	12.5	**4.5**	201	4.0	7.6	105	7.8
RLA	100.0	6.5	402	5.6	5.4	469	11.7
RCS	400.0	23.0	805	2.1	10.2	396	4.7
RCS	750.0	27.0	805	2.1	4.8	393	7.2
					27.1		34.8

- Now exploring dogbone RLAs with multipass arcs (design for 2 energies)



Droplet arc:
- 60° outward bend
- 300° inward bend
- 60° outward bend





– should be less costly

– looks promising!

“Acceleration and Ring” session

ILLINOIS INSTITUTE OF TECHNOLOGY
Transforming Lives. Inventing the Future. www.iit.edu

2. Alexahin: Ring lattices

"Acceleration and Ring" session

2. Alexahin: Ring lattices

- Lattice design
  - 1.5 TeV c.o.m Lattice
  - New 3 TeV c.o.m Lattice
- Fringe Field and Multipole Errors
- Strong-Strong Beam-Beam Simulations
- Plans

“Acceleration and Ring” session

2. Alexahin: Ring lattices

- **Lattice design**
  - 1.5 TeV c.o.m Lattice
    - Solution devised with $\beta^* = 1$ cm
      - displaced FF quad doublets to sweep decay electrons and give robust chromaticity correction
    - But large $\beta y\_max \rightarrow$ high sensitivity to magnet errors, and approach may not work at higher energy

"Acceleration and Ring" session

2. Alexahin: Ring lattices

- Lattice design
  - 1.5 TeV c.o.m Lattice
  - New 3 TeV c.o.m Lattice
- Fringe Field and Multipole Errors
- Strong-Strong Beam-Beam Simulations
- Plans

“Acceleration and Ring” session

2. Alexahin: Ring lattices

- **Lattice design**
  - 1.5 TeV c.o.m Lattice
  - New 3 TeV c.o.m Lattice
    - Solution devised with undisplaced FF quad triplets, gives 0.5 cm β^*
    - Solves βy_max problem, but concerned about horizontal stability

"Acceleration and Ring" session

2. Alexahin: Ring lattices

- Lattice design
  - 1.5 TeV c.o.m Lattice
  - New 3 TeV c.o.m Lattice
- Fringe Field and Multipole Errors
- Strong-Strong Beam-Beam Simulations
- Plans

"Acceleration and Ring" session

2. Alexahin: Ring lattices

- Lattice design
  - 1.5 TeV c.o.m Lattice
  - New 3 TeV c.o.m Lattice
- Fringe Field and Multipole Errors
- Strong-Strong Beam-Beam Simulations
- Plans
  - Seek compromise solution, explore sensitivity to errors, etc.
  - Need more manpower!

“Acceleration and Ring” session

3. Summers: Fast Ramping 750 GeV Muon Synchrotron

“Acceleration and Ring” session

3. Summers: Fast Ramping 750 GeV Muon Synchrotron

Muon Acceleration Summary

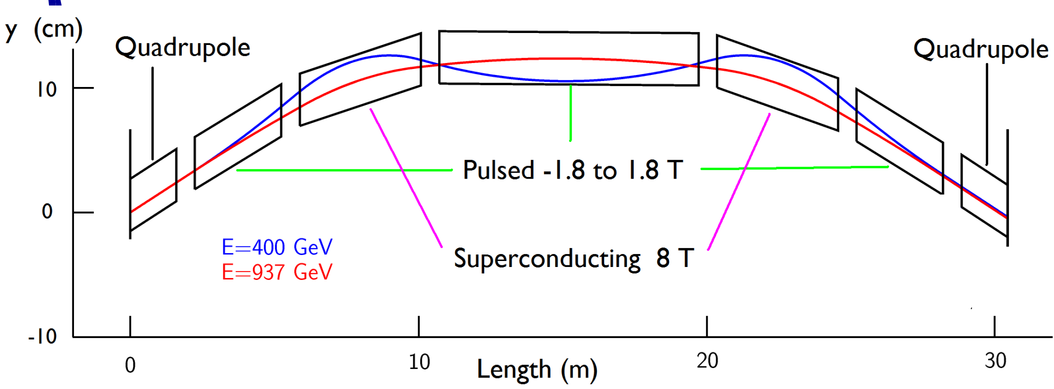
- Synchrotrons are a lot less expensive than racetracks
- 400 Hz, 1.8 T dipole prototype is in progress.
  Mitred laminations from Pacific Laser Laminations are ready
  Need to see how well the magnetic flux circuit works.
- Al Garren and Scott Berg are working on interleaved lattice.
  What magnet errors can be tolerated? Gap is small.
  Hexapole fields in beam pipe.
- Trying to optimize keeping in phase with 1.3 GHz SRF
  PAC07: Adjust orbit radius & use 2 rings. 100 $\rightarrow$ 400 $\rightarrow$ 750
  1.5 TeV $\mu^+\mu^-$ collider. D. Summers et al., arXiv:0707.0302

"Acceleration and Ring" session

3. Summers: Fast Ramping 750 GeV Muon Synchrotron

Muon Acceleration Summary

- Synchrotrons are a lot less expensive than racetracks
- 400 Hz, 1.8 T dipole prototype is in progress.
  Mitred laminations from Pacific Laser Laminations are ready
  Need to see how well the magnetic flux circuit works.
- Al Garren and Scott Berg are working on interleaved lattice.
  What magnet errors can be tolerated? Gap is small.
  Hexapole fields in beam pipe.
- Trying to optimize keeping in phase with 1.3 GHz SRF
  PAC07: Adjust orbit radius & use 2 rings. 100 $\longrightarrow$ 400 $\longrightarrow$ 750
  1.5 TeV $\mu^+\mu^-$ collider. D. Summers et al., arXiv:0707.0302

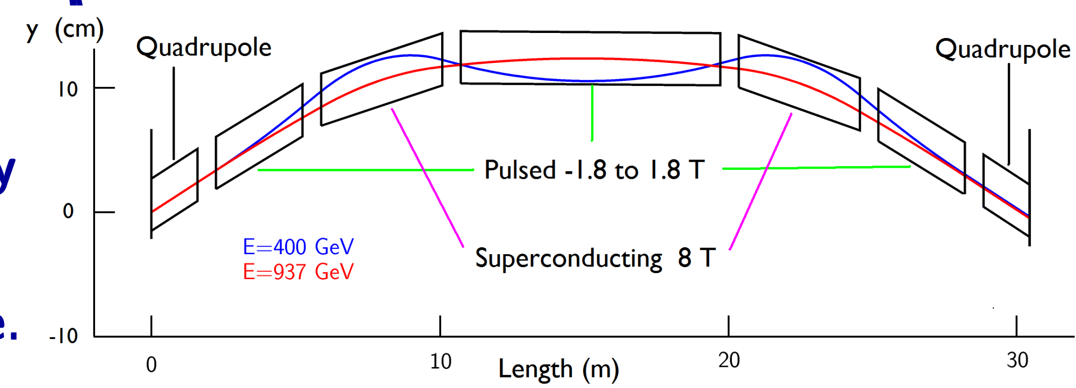


"Acceleration and Ring" session

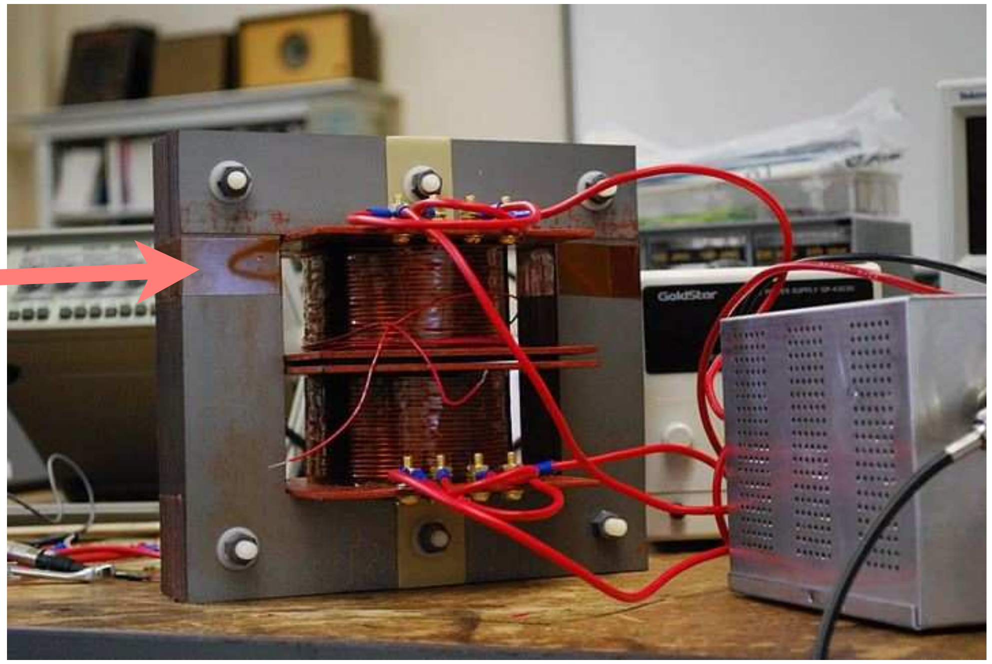
3. Summers: Fast Ramping 750 GeV Muon Synchrotron

Muon Acceleration Summary

- Synchrotrons are a lot less expensive than racetracks
- 400 Hz, 1.8 T dipole prototype is in progress.
  Mitred laminations from Pacific Laser Laminations are ready
  Need to see how well the magnetic flux circuit works.
- Al Garren and Scott Berg are working on interleaved lattice.
  What magnet errors can be tolerated? Gap is small.
  Hexapole fields in beam pipe.
- Trying to optimize keeping in phase with 1.3 GHz SRF
  PAC07: Adjust orbit radius & use 2 rings. 100 $\rightarrow$ 400 $\rightarrow$ 750
  1.5 TeV $\mu^+\mu^-$ collider. D. Summers et al., arXiv:0707.0302



Grain Oriented Silicon Steel Dipole Prototype



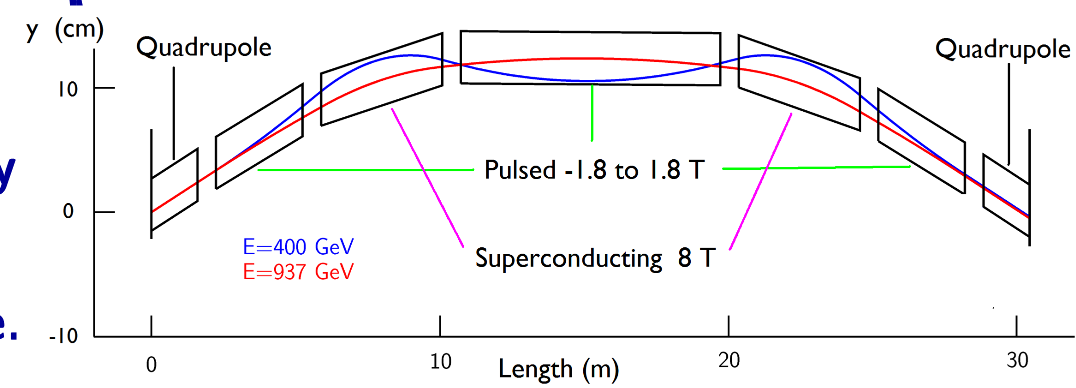
– 1st prototype revealed saturation problems (due to "T" joints?)

"Acceleration and Ring" session

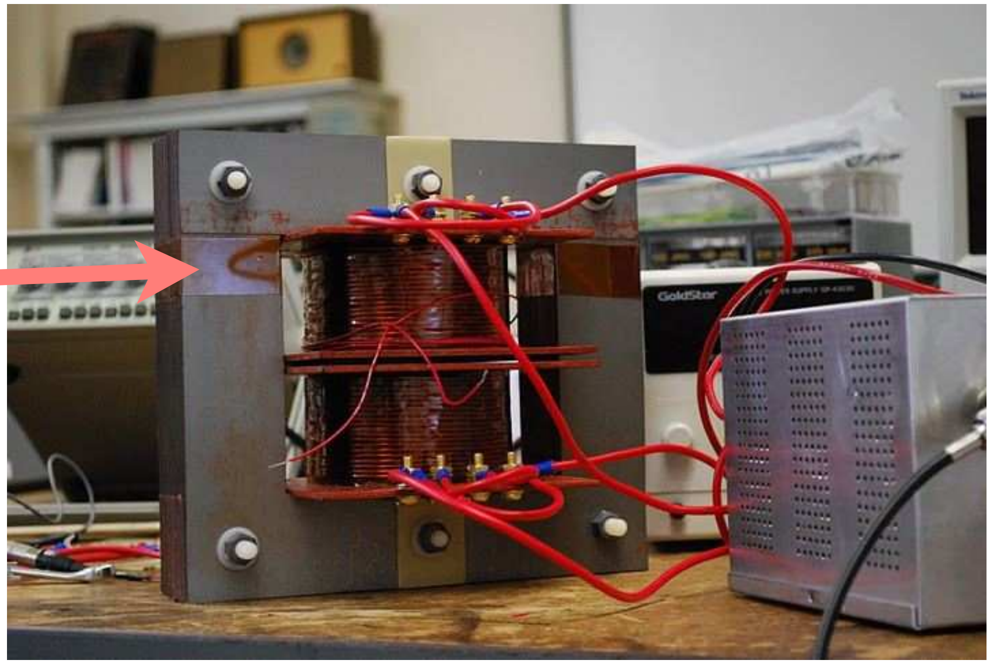
3. Summers: Fast Ramping 750 GeV Muon Synchrotron

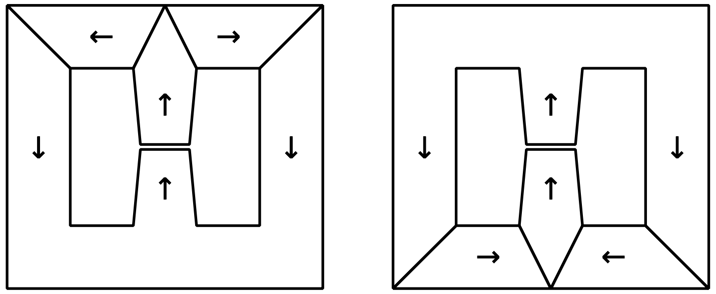
Muon Acceleration Summary

- Synchrotrons are a lot less expensive than racetracks
- 400 Hz, 1.8 T dipole prototype is in progress.
  Mitred laminations from Pacific Laser Laminations are ready
  Need to see how well the magnetic flux circuit works.
- Al Garren and Scott Berg are working on interleaved lattice.
  What magnet errors can be tolerated? Gap is small.
  Hexapole fields in beam pipe.
- Trying to optimize keeping in phase with 1.3 GHz SRF
  PAC07: Adjust orbit radius & use 2 rings. 100 $\rightarrow$ 400 $\rightarrow$ 750
  1.5 TeV $\mu^+\mu^-$ collider. D. Summers et al., arXiv:0707.0302



Grain Oriented Silicon Steel Dipole Prototype





- 1st prototype revealed saturation problems (due to "T" joints?)
- Hope for improvement using mitred laminations

Conclusions (1)

Conclusions (1)

- Muon capture already ≈ optimized
  – but can still benefit from tweaking
- Helical channels good for bunch combining
- Cooling designs well along, now need more realistic simulations
  – 3 main 6D-cooling options, 2 final
  – aim for FY12 down-select
- MICE cooling demo progressing towards ≈ 2014 conclusion

Conclusions (1)

- Muon capture already ≈ optimized
  - but can still benefit from tweaking
- Helical channels good for bunch combining
- Cooling designs well along, now need more realistic simulations
  - 3 main 6D-cooling options, 2 final
  - aim for FY12 down-select
- MICE cooling demo progressing towards ≈ 2014 conclusion
- Magnets: 40T challenging, but good progress
- Acceleration: exploring potentially lower-cost solutions
  - RLA design optimization
- Storage-rings: difficult constraints, but solutions being found
  - need to ramp up effort

Conclusions (2)

- Neuffer's conclusions:

Conclusions (2)

- Neuffer's conclusions: